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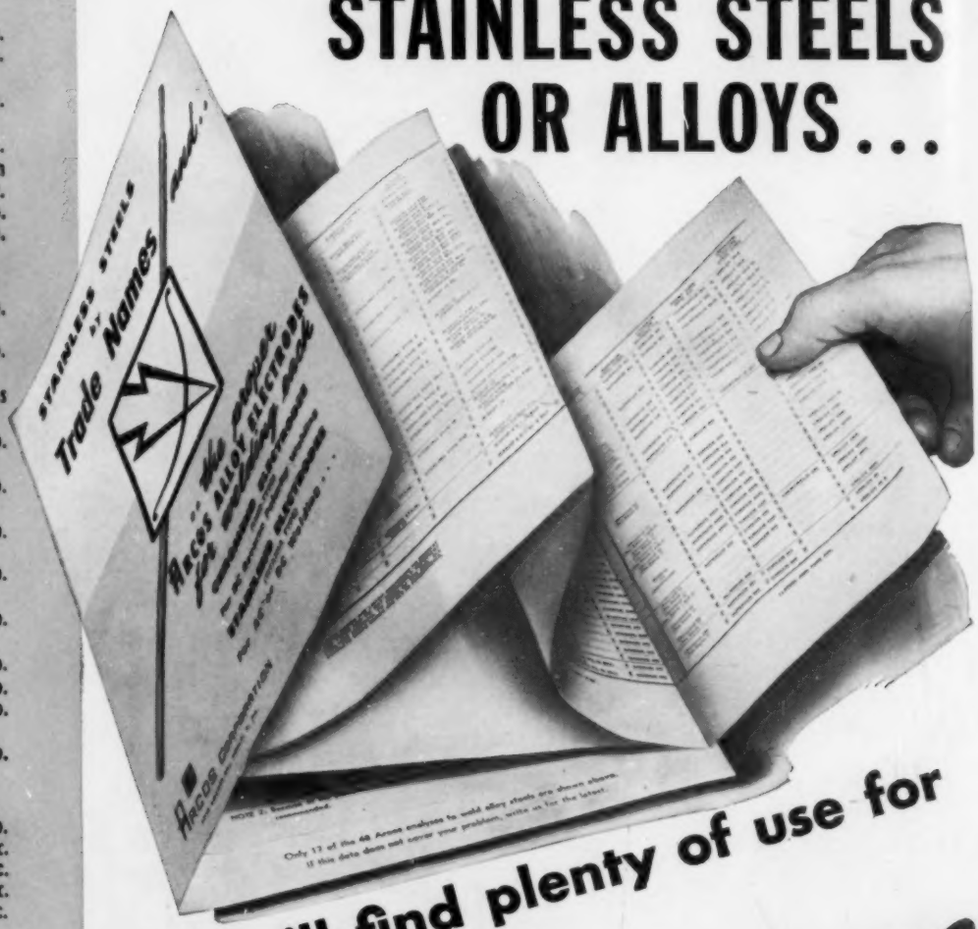

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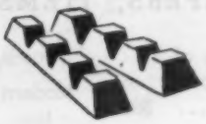
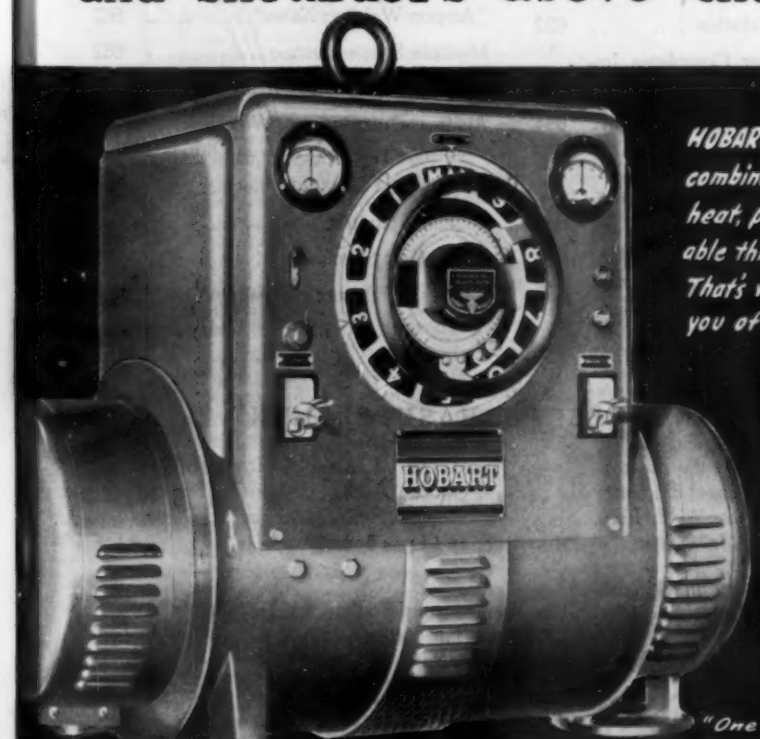
well sir, HOBART has more "innards" than most arc welders. The liberal design of a HOBART you'll find has more copper, more steel,  more good insulation, precision bearings and accurate controls, all engineered into a simplified arc welder which makes its performance stand out head and shoulders above the pack.



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Factors Controlling the Strength of Brazed Joints from Final Report N.R.C. 560*

By C. Rhyne, Jr.†

Abstract

This report gives experimental results on the strength of furnace-brazed joints with copper as the brazing metal. It is particularly concerned with data that may be used in aircraft subassemblies. The parent metals are limited to S.A.E. 4130 and S.A.E. 1010 steels.

Joints of aircraft tubing in sizes from 1/4 to 3-in. have been investigated with particular emphasis on the 1 x 0.120-in. wall tubing. Some results on tube-to-tube joints and ring and plug joints have been investigated.

Factors investigated as contributing to the strength of the joints were:

1. Area of the bond.
2. Finish of surfaces.
3. Clearances between the mating members.
4. Protective atmosphere during brazing.
5. Time of brazing.
6. Parent metal of members.
7. Heat treatment after brazing.
8. Contamination of surface.
9. Diameter and thickness of members.
10. Misalignment of brazed members.

The ultimate strength of the joint is expressed in average shear stress in the circumferential area between the mating members, based on the assumption that the joints are loaded in tension or compression in a line actually through the center of the joints.

The most predominant factor contributing to the strength of a joint is shown to be the deformation of the parent metal at the time of the failure of the bond. The average ultimate stress of the bond may vary between approximately 45,000 psi. at 0 stress for high-strength steels to 17,000 for S.A.E. 1010 steel when the tensile stress of the parent metal approaches its ultimate value.

Factors such as finish, clearance, atmosphere and time within the limits ordinarily used do not have a great effect on the strength of the tube joints (less than 7% average).

Misalignment of the brazed parts decreases the strength and makes the results erratic.

It is impossible to predict the exact strength of a single brazed joint in practice as close as that of the parent metal. All results have considerable scatter, such that on the average, 90% of the brazed joints may vary as much as 10.5% from their value as predicted by these data. It is, however, reasonable to expect to braze in production samples consistently above 25,000 psi. shear stress average for most of the joints of S.A.E. 4130 steel and 15,000 psi. of S.A.E. 1010 steel on a wide range of values of the above-mentioned variables.

* Issued by Office of Production Research and Development, War Production Board. Professional Engineer, Marianna, Fla.
† Formerly Industrial Heating and Welding Engineering Division, General Electric Co., Schenectady, N. Y.

Introduction

FURNACE brazing is a process for joining metal wherein two members to be joined are placed in intimate contact with a lower melting point material in or near the joint and the assembly placed in a furnace and heated until the brazing metal melts and flows into the joint. This produces a bond between the members when the assembly cools. The process has been in limited use for more than 20 years with copper as the principal brazing material and steel as the parent metal. The process has not, however, been limited to copper but has been used with great success with lower melting point alloys such as brass and the so-called silver solders, the latter brazing materials finding their particular application in joining metals with melting temperatures lower than copper and for assemblies that might be damaged by the high temperature of the brazing process (approximately 2050° F.).

The furnace used for brazing usually is filled with a protective atmosphere that is reducing to any oxides of the brazing metal or the parent metal such that the surface of the materials may be maintained clean during the brazing and in the subsequent cooling. This atmosphere may be any of a number of mixtures of carbon-monoxide and hydrogen in large percentages, with smaller content of oxidizing gases such as carbon dioxide and water vapor.

In industrial brazing the atmosphere is generally produced by a gas generator utilizing some hydrocarbon gas and air and sometimes some solid carbon material such as charcoal. The gas is introduced into the furnace at a pressure only slightly above atmospheric and the flow of gas through the furnace doors and other openings prevents the polution of the furnace interior with air and sometimes water vapor.

In most cases the parts to be joined are male and female members with tight fits such that dimensional relationship is retained in the furnace, even at the brazing temperature. It is generally necessary to machine the two mating parts prior to brazing to provide correct clearance and surface finish. In some cases the parts are supported by jigs or fixtures in the furnace during brazing to maintain their alignment, or the parts may be riveted, tack welded or staked to aid their rigidity. Parts are generally positioned during brazing such that the flow of copper is horizontal or downward although

occasionally joints are brazed requiring upward flow by capillary action.

The time to produce a braze is generally all of the time necessary to heat the part and the copper to the melting point of the copper. Literature on copper brazing has indicated that the strength of the joint may be changed somewhat by varying the length of time that the part is allowed to remain at the brazing temperature after the copper has melted, the rate at which it is heated, and the rate at which it is cooled.

In general, almost any machined surface finish is regarded as applicable to brazing except extreme polished surfaces and extreme rough surfaces. It is generally understood that the flow of copper is accelerated by the moderately rough finishes, provided no extreme recesses perpendicular to the direction of travel impede the flow.

Some furnace atmospheres have been noted as aiding the flow of copper but no data have been available on the effect of these atmospheres on the strength of a joint wherein the copper has covered the area available. Data are available, however, to show that although some of the atmospheres are reducing, they may also be decarburizing at the high brazing temperature and therefore the parent metal is weakened because of the carbon removed from the surface.

The strength of a copper-brazed joint is generally expressed in ultimate shear stress in the bonded area between the two telescopic members. This assumes that the two members are stressed axially in such a manner that the total load in tension or compression produces in the bonded area a shear stress equal to the load divided by the circumferential area. The usual low limit of the ultimate strength of such a joint has been thought of as 20,000 psi.; approximately the shear stress of the cast copper in the joint. Stresses approaching 40,000 or 50,000 psi. have been reported for some copper-brazed joints. The high value of these stresses compared to the strength of the copper itself is attributed to the formation of alloys of copper and steel in the bond with higher strengths than copper and sometimes higher than the parent metal. It is generally understood that the ultimate strength of the joint increases with the tightness of fit between the members, particularly in the case of members strong enough to retain the press fit at the brazing temperature.

Data, however, on the strength of joint as affected by clearance, finish, time, atmospheres, size of mating members, contamination of surfaces, types of joints and subsequent heat treatment are meager and are confined chiefly to the files of manufacturers using the brazing process.

A summary of brazing literature was made by L. L. Wyman, War Metallurgy Committee, in a report on N.R.D.C. Survey Project FC-13. This survey led to the request by the A.W.P.C. Testing and Research Panel of the West Coast, for an investigation of some of those factors affecting the strength of brazed joints. This investigation described in this report was therefore initiated with L. L. Wyman, War Metallurgy Committee, as Research Supervisor, R. D. Van Nordstrand, General Electric Co., Technical Representative, and C. Rhyne, Jr., as chief investigator. Contract W.P.B.-179 was placed with the General Electric Co. to conduct this work.

Experimental Work

Test Specimens

The various specimens tested are shown in Fig. 1. The following is a brief description of the samples brazed:

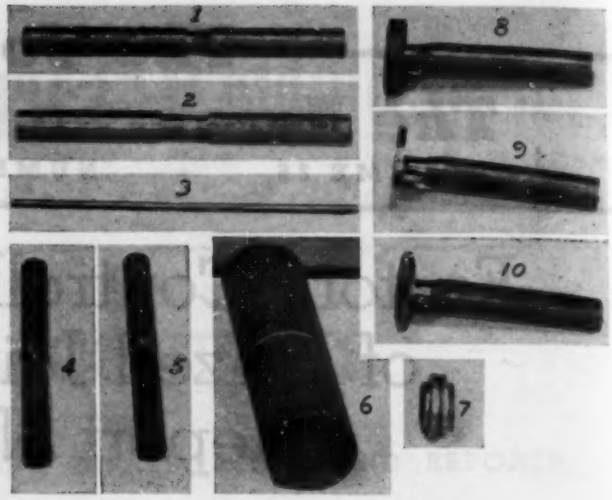


Fig. 1—Samples Tested

1. Male member 1- x 0.120-in. diam. wall tubing swaged and machined to telescope inside 1- x 0.120-in. diam. wall machined female member.
2. 1-in. diam. solid male plugs telescoping into machined interior of 1- x 0.120-in. wall female member machined to wall thickness of 0.020-in. at joints. (Not machined for some tests.)
3. $^1/_4$-in. O.D. x 0.035-in. wall male member swaged and machined to mate with $^1/_4$- x 0.035-in. wall machined female member.
4. 1- x 0.120-in. diam. swaged male member machined at joints to 0.020-in. wall, telescoped into 1- x 0.120-in. wall female member.
5. 1- x 0.120-in. wall tube swaged and machined at joint to telescope into 1- x 0.035-in. wall machined female member.
6. 3- x 0.065-in. wall tube swaged and machined at joint to telescope into 3- x 0.065-in. wall machined female member.
7. Solid $1^1/_2$-in. O.D. x 1-in. long plug ($^1/_2$-in. long in some tests) mated with 2-in. O.D. by $^1/_2$-in. wide ring.
8. 1- x 0.120-in. diam. tube swaged and machined at joint to mate with $2^1/_2$ in. diam. by $^1/_2$-in. thick ring. (Not machined in one test.)
9. 1- x 0.120-in. wall male tube swaged and machined at joint to mate with $2^1/_4$-in. diam. by $^1/_4$-in. ring.
10. 1- x 0.120-in. wall male tube swaged and machined to mate with $2^1/_4$-in. diam. by $^1/_8$-in. thick ring. (Less than $^1/_8$-in. in some tests.)

All of the tubes were 6-in. long and all of the joints prior to brazing were machined on a lathe with the exception of one group of Sample 1 and one group of sample 8 that were shot blasted.

On all the tube joints copper was applied by means of a single ring of wire on the interior of the female member before mating with the male member. In addition, the large tube (see Fig. 1, sample 6) had an additional ring of copper applied to the outside of the tube. The ring and plug samples (see Fig. 1, sample 7) had a single copper wire on one side of the male member (upper side). The tube to plate joints, samples 8, 9 and 10, had a single ring of copper placed around the male member after it passed through the female member. (Figure 1 shows samples 8, 9 and 10 after the end had been machined off as will be described later.)

The amount of overlap area on samples 1, 2 and 4 was established approximately by slipping or pressing the

male member the desired distance into the female member. On samples 3, 5 and 6 the overlap area was established by first brazing with a large overlap, then machining back to leave the desired bonded area. Samples 1, 2 and 4 had no machining after brazing except the removal of the outside fillets (removal of the inside fillet was almost impossible and therefore not attempted). Sample 7 had both fillets machined after brazing (except in one case mentioned later). Samples 8, 9 and 10 had fillets removed from both sides and some additional metal to improve alignment.

Method of Testing

All the tube-to-tube joints, tube-to-plug joints and tube-to-ring joints ruptured (Fig. 1, samples 1, 2, 3, 4, 5, 6, 8, 9 and 10) were pulled on a Baldwin Southwark hydraulic testing machine. Plugs in the tube ends prevented collapsing of the tube in the jaws of the tester.

Sample 7 was ruptured by placing the specimen in a hardened ring on the testing machine, placing a ball in a recess on one side of the male member and applying pressure to the top of the ball. (In some of the first tests this ball was not used.)

All of these samples, unless otherwise noted, failed by rupture of the bond between the male and female members. Results were tabulated in terms of average shear stress in the bond, based on the load required to produce failure in tension or compression, divided by the circumferential bond area.

Furnace

All of the samples were brazed in a standard box-type brazing furnace 29 KW, 12 x 36 x 8-in. high with a water-jacketed cooling chamber (see Fig. 14). A reducing atmosphere was used in the furnace and in the cooling chamber, during both the heating and the cooling cycles.

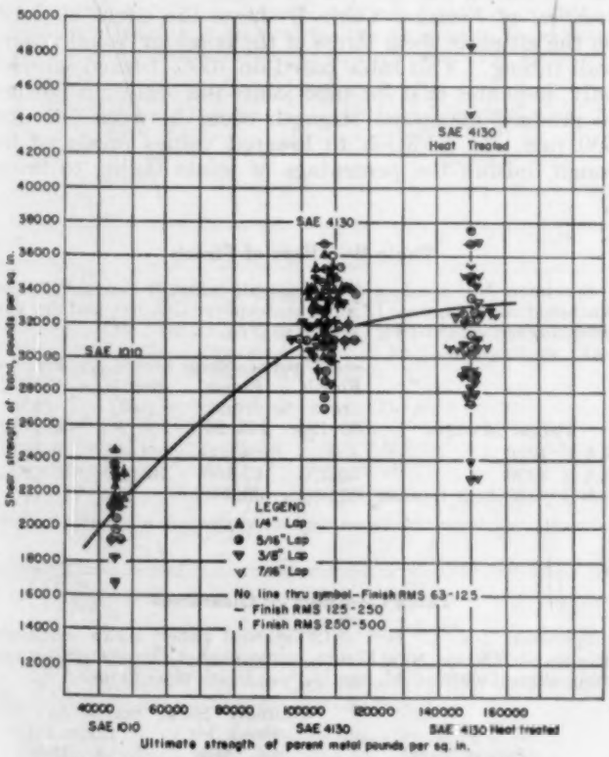


Fig. 2—Shear Strength vs. Stress in Parent Metal

Copper-brazed joints—1- x 0.120-in.-wall tubing, time 12 min., atmosphere CO_2-free and dry gas, machine finish below 500 rms. not heat treated.

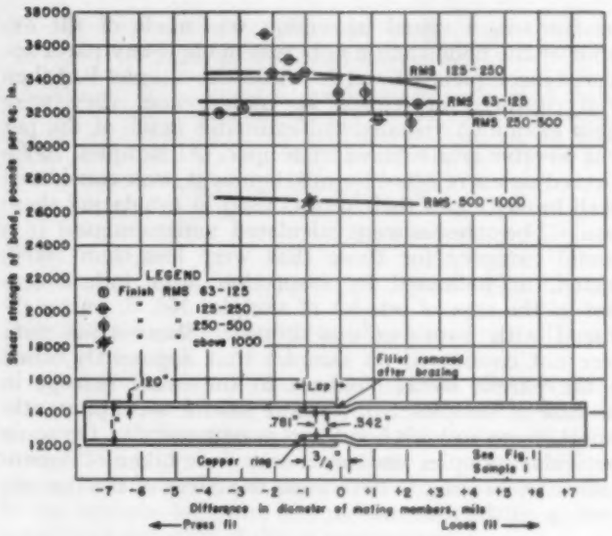


Fig. 3—Shear Strength of Bond vs. Clearance

Copper-brazed joints—1- x 0.120-in.-wall S.A.E. 4130 tubing, lap 5/16 in., time 24 min., atmosphere CO_2-free and dry gas, machine finishes, misalignment less than 0.4°, not heat treated.

The purity of the particular atmosphere was measured shortly before or after each run. All tube samples were loaded approximately 6 per tray and, except for several first loads, were unsupported in the furnace during brazing or cooling. The tray was placed in the furnace for the prescribed total time with the furnace control set at 2050° F., then pushed into the cooling chamber maintained at approximately 150° F., until the specimens had cooled to a temperature below the oxidation range. No flux was used with any of the samples brazed.

Finish

All finishes, unless otherwise noted, were produced on a lathe to the desired degree of surface roughness. The actual value of this finish was measured on a profilometer and expressed in root mean square depth of scratch from 63 to 1000 microinches. In the case of one lot of No. 1 samples the surfaces were first machined smooth and then shot blasted. One lot of No. 1 samples were purposely oxidized and another lot purposely oiled before brazing. All remaining samples were degreased and had a clean machined finish at the time of brazing.

Alignment of Members

The alignment of the male member with respect to the female member was measured after brazing on all samples tested. In the case of samples 1, 2, 3, 4, 5, 6 and 7, nothing was done to correct this after brazing except the rejection of poorly aligned specimens from the data. However, on samples 8, 9 and 10 the base of the ring was machined perpendicular to the axis of the male member after brazing in order that in the jaws of the testing machine, the stress of the bond would be approximately axial. In the case of sample 1 no results were considered in which the female member was misaligned from the male member more than 0.4°.

Clearance

The clearance between the mating members was expressed in terms of difference of diameter. This clearance was the result of measurements taken prior to brazing.

Inspection of Specimens

Immediately after the samples were removed from

the furnace, a visual inspection was made of the exterior of the bonds and a note was made if any parts appeared incompletely brazed. After the samples had then been ruptured in tension or compression, they were again examined visually and estimates made of the per cent possible area covered by copper. All samples, 100% covered unless rejected for misalignment, were considered "well brazed" and their results used in tabulating these data. The stresses were calculated and tabulated in a second category for those that were less than 100% brazed, as indicated by inspection after failure (except in the case of one lot of samples No. 6, purposely brazed with improper machining). Shear-stress data were not considered on samples that apparently failed in the parent metal adjacent to the braze (except in the case of samples No. 6 where failure was apparently simultaneous in both bond and parent metal). On some particular samples measurements were taken of dimensions after brazing to determine the effect of the furnace heating on the dimensions.

Heat Treatment of Specimens

Except in the case of some specimens of sample No. 1, no heat treatment was given to specimens after brazing. All specimens were normalized at 1650° F. for 1 hr. after swaging prior to machining. Analysis was made of the materials used before brazing and some photomicrographs were taken after brazing to determine the effects of the furnace temperature on the parent metal and on the bond. One particular lot of S.A.E. 4130 samples No. 1 were heat treated to 150,000 psi. after brazing before rupture.

Decarburization

Photomicrographs were taken on several samples on the interior and exterior of the walls to determine the extent of decarburization as received. Further photomicrographs were taken after the normalizing and after the brazing processes.

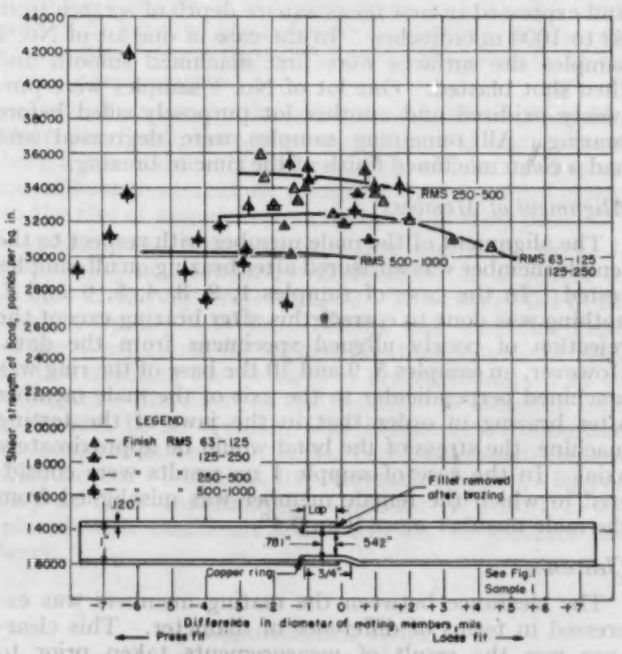


Fig. 4—Shear Strength of Bond vs. Clearance

Copper-brazed joints—1- x 0.120-in.-wall S.A.E. 4130 tubing, lap 1/4 in., time 12 min., atmosphere CO_2-free and dry gas, machine finishes, misalignment less than 0.4°, not heat treated.

Table A—Effect of Lap

Specimen No. 1. 1- x 0.120-in.-wall tubes, 0 clearance, clean machined surfaces 63–500 rms., time 12 min., atmosphere CO_2-free and dry gas, tubes aligned within 0.4°.

	—Ultimate Shear Stress, Av. Psi.—			
Parent Material	Lap 3/16 In.	Lap 1/4 In.	Lap 5/16 In.	Lap 3/8 In.
S.A.E. 1010	26,600	23,100	20,200	17,500
S.A.E. 4130	33,860	33,450	30,700	29,730
S.A.E. 4130 heat treated	..	35,450	31,750	30,200

Results

Tube-to-Tube Joints

A general idea of the relative magnitude of the shear stresses to be expected in copper-brazed joints is shown in Fig. 2 for 1- x 0.120-in. tube-to-tube joints, not misaligned more than 0.4°. This includes S.A.E. 4130 steel at 116,900 psi., S.A.E. 4130 steel, heat treated after brazing to 150,000 psi., and S.A.E. 1010 steel at 45,000 psi. ultimate tensile stress. It includes a range of finish of 63 to 500 rms., a range of clearance of 5 mils press fit to 5 mils loose fit per inch diameter. It does not exclude those samples which were partially brazed, even though they were noted as incompletely brazed before testing. (See tables K and L for incompletely brazed joints.) Figures 3 and 4 show typical results for one condition of overlap area with clearance and finish of variables.

Effect of Lap.—Table A shows the effect of lap on two different kinds of steel for 1- x 0.120-in. wall tubes for fixed conditions of atmosphere, time, surface cleanliness and range of finishes.

This table shows that the ultimate shear stress of the bond increases with decreasing overlap for the same thickness of tubing wall and parent metal.

Effect of Finish.—Table B shows the effect of finish on the ultimate shear stress of the bond for 1- x 0.120-in. wall tubing. This table based on 100% brazed samples only, indicates that for tube joints the optimum finishes to produce maximum strength occur between 125 and 500 rms. In addition to lowered values produced by rough finishes the percentage of joints failing to braze

Table B—Effect of Finish

Specimen No. 1. 1- x 0.120-in.-wall tubes, 0 clearance, clean machined surfaces, time 12 min., atmosphere CO_2-free and dry gas, tubes aligned within 0.4°, Laps 1/4 in., 5/16, 3/8 in.

	—Ultimate Shear Stress, Av. Psi.—			
Parent Material	Finish, rms. 63–125	Finish, rms. 125–250	Finish, rms. 250–500	Finish, rms. 500–1000
S.A.E. 1010	...	24,000	22,400	19,600
S.A.E. 4130	30,370	31,160	32,030	28,930
S.A.E. 4130 heat treated	32,930	33,600	...	....

Table C—Effect of Clearance

Specimen No. 1. 1- x 0.120-in.-wall tubes, clean machined finishes 63–500 rms, time 12 min., atmosphere CO_2-free and dry gas, tubes aligned within 0.4°, laps 1/4, 5/16, 3/8 in., time 12 min.

	Ultimate Shear Stress Av. Psi.	
Parent Metal	Press Fit, 4 Mils	Loose Fit, 4 Mils
S.A.E. 1010	20,600	20,100
S.A.E. 4130	31,700	30,500
S.A.E. 4130 heat treated	33,300	31,800

Table D—Effect of Atmosphere

Specimen No. 1. 1- x 0.120-in.-wall tubes, clean machined finishes 63–500 rms, tubes aligned within 0.4°, laps $^5/_{16}$ in., parent metal S.A.E. 4130, time 12 min.

Ultimate Shear Stress, Av. Psi.		
CO_2-Free and Dry Gas	Partially Combusted Gas	Drycolene
30,700	30,550	31,150

Table E—Effect of Time

Specimen No. 1. 1- x 0.120-in.-wall tubes, clean machined finishes 63–500 rms, tubes aligned within 0.4°, laps $^5/_{16}$ in., parent metal S.A.E. 4130, atmosphere CO_2-free and dry gas.

Ultimate Shear Stress, Av. Psi	
Time, 12 Min.	Time, 24 Min.
30,700	32,900

Table F—Effect of Contamination of Surface

Specimen No. 1. 1- x 0.120-in.-wall tubes, machined surfaces 125–250 rms., 0 clearance, laps $^3/_8$ in., tubes aligned within 0.4°, CO_2-free and dry gas, time 12 min.

Clean	Dipped in No. 50 Oil Before Brazing	Oxidized Before Brazing
31,000	29,400	29,200

Table G—Effect of Shot Blasting

Specimen No. 1. 1- x 0.120-in.-wall tubes, machined surfaces prior to shot blasting, finish rms. 63–250, 0 clearance, atmosphere CO_2-free and dry gas, time 12 min., parent metal S.A.E. 4130.

Ultimate Shear Stress, Av. Psi.	
Clean Machined Surfaces Not Shot Blast	Surfaces Machined Then Shot Blast
31,000	26,400

Table H—Effect of Diameter

Specimen No. 1, 3-, 5- and 6-tube joints, clean machined surfaces, finish rms. 63–250, 0 clearance, time 12 min., atmosphere CO_2-free and dry gas, parent metal S.A.E. 4130.

Ultimate Shear Stress, Av. Psi.			
No. 1 1- x 0.120-In. Wall	No. 5 1- x 0.035-In. Wall	No. 3 $^1/_4$- x 0.035-In. Wall	No. 6 3 x 0.065-In. Wall
30,000	35,400	40,300	22,000

Table I—Ring and Plug Joints

Specimen No. 7. 1-in. diam. plugs $^1/_2$ in. and 1 in. long brazed to 2-in. O.D. rings $^1/_2$ in. wide, clearance −4 mils to +4 mils, atmosphere CO_2-free and dry gas, time 30 min.

Finish	Ultimate Shear Stress, Av. Psi. S.A.E. 1010	S.A.E. 4130
63–125	....	28,400
125–250	35,100	25,800
250–500	31,800	31,800

Table J—Tube and Plug Joints

Specimen No. 2 (except no machining on exterior of female member). Clean machined surfaces 63–125 rms., 0 clearance, atmosphere CO_2-free and dry gas, time 30 min., parent metal S.A.E. 4130, $^5/_{16}$-in. lap, 1- x 0.120-in.-wall tube to 0.781-in. plug

Ultimate Shear Stress, Psi.	
No. 1 Tube to Tube Joint, 24 Min.	Specimens as Described
32,600	37,200

increases tremendously with finishes above rms. 500 as is shown on Table K.

Effect of Clearance.—Table C shows the effect of fit for 1- x 0.120-in. wall tube joint or three different conditions of parent metal and for a range of finishes from 63 to 500 rms. This table indicates that there is only a small decrease in strength from the extreme press fits of 4 mils to the extreme loose fits of 4 mils for tube joints. For a possible explanation of this, see discussion.

Effect of Atmosphere.—Table D shows the variation of strength with three different furnace atmospheres. This table indicates that there is little variation in strength with the atmospheres tested. Refer, however, to Fig. 10 for the effect of atmosphere on the parent metals.

Effect of Time.—Table E shows the effect of time at the brazing temperature on S.A.E. 4130, 1- x 0.120-in. wall tubing joints. This indicates that there is a slight increase in strength due to increasing time at the brazing temperature. (See photomicrographs Figs. 11, 12 and 13 for effect on parent metal.)

Effect of Parent Metal.—Figure 2 shows the variation in average shear stress with ultimate strength of parent metal. This shows that for a wide range of fits, finishes and clearances the average ultimate stress of the braze increases with increase in ultimate strength of the parent metal.

Effect of Heat Treatment After Brazing.—Tables A, B and C and Fig. 2 show slightly higher ultimate shear stress values for S.A.E. 4130 tube joints heat treated to 150,000 psi. after brazing.

Table K—Record of Failures Tube Joints No. 1

Clean machined surfaces, clearance −4 mils to +4 mils, all atmospheres, time 12 and 24 min., all laps.

	Finish 63–500		Finish 500–1000	
	S.A.E. 4130	S.A.E. 1010	S.A.E. 4130	S.A.E. 1010
Specimens brazed	269	51	264	51
Specimens not 100% brazed	7	2	135	4
Per cent of failures	2.6	3.9	51.1	7.8
Failures due to improper machining	2		Not checked	Not checked
Failures due to operator faults	1		Not checked	Not checked
Failures unaccounted for	4	2	135	4
Ultimate shear stress of failures based on total possible bond area	20,600 26,800 29,500 25,300 29,500 24,000 21,700	9,390 25,600	Not checked	Not checked

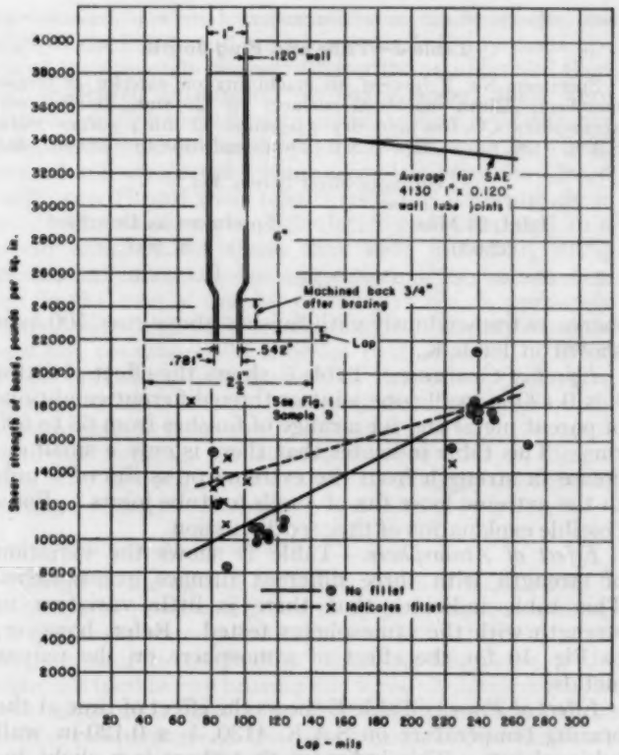

Shear strength of bond, pounds per sq. in.
Lap - mils
.120" wall
Average for SAE 4130 1" x 0.120" wall tube joints
Machined back 3/4" after brazing
Lap
See Fig. 1 Sample 9
No fillet
Indicates fillet

Fig. 5—Shear Strength Bond vs. Lap

Copper-brazed joints—1- x 0.120-in.-wall S.A.E. 4130 tube and ring joints, time 12 min., atmosphere CO_2-free and dry gas, finish between 125–250 rms., not heat treated.

Effect of Contamination of Surface Before Brazing.—Table F shows comparative average ultimate shear-stress values for one lot of tubes oxidized prior to brazing and one lot dipped in No. 50 oil prior to brazing.

Effect of Diameter and Wall Thickness.—Table H shows average values of ultimate shear stress for 4130 steel tubes 1- x 0.120-in. wall, 1- x 0.035-in. wall, $^1/_4$- x 0.035-in. wall and 3- x 0.065-in. wall.

Effect of Shot Blasting.—Table G gives average ultimate stress values for one lot of specimens shot blasted prior to brazing and a comparison with similar machined specimens.

Tube and Ring Joints

Figure 5 gives average shear-stress values for S.A.E. 4130 tube-to-ring joints numbers 9 and 10 with machined finishes.

Ring and Plug Joints

Ring and plug samples No. 7 were tested in both S.A.E. 4130 and S.A.E. 1010 steel covering a range of fits from 4 mils press to 6 mils loose and a range of finishes from 63 rms. to 500 rms. These specimens were loaded in compression to produce shear in the circumferential bond. Table I summarizes these results and Fig. 6 shows a plot of a typical test.

Table L—Record of Failures Tube Joints No. 1

Clearance −1.5 to +1.5, laps $^1/_4$ to $^7/_{16}$ in., CO_2-free and dry gas, time 12 min., finish 63–250 rms.

	Shot Blasted Prior to Brazing	Oiled Prior to Brazing	Oxidized Prior to Brazing
Number of specimens brazed	47	10	8
Number failed to braze 100%	0	1	1
Number of failures unaccounted for	0	1	1
Ultimate shear stress of failure based on possible area, psi.	..	28,000	30,000

Table M—Record of Failures Ring and Plug Joints No. 7

One-inch diam. plugs $^1/_2$ in. and 1 in. long brazed to 2-in. O.D. rings $^1/_2$ in. wide. Clearance −4 mils to +4 mils, atmosphere CO_2-free and dry gas, finish 63–500 rms. machined surfaces.

	S.A.E. 4130	S.A.E. 1010
Number of specimens brazed	62	49
Number failed to braze 100%	8	4
Number of failures unaccounted for	8	4
Ultimate stress of failures based on possible area, psi.	17,400	8,200
	26,900	10,150
	17,500	5,500
	29,000	30,900
	21,800	
	18,800	
	24,200	

Tube and Plug Joints

Table J shows results of 1- x 0.120-in. wall tubes brazed to solid plugs. This table shows the comparison in ultimate shear stress to that of 1- x 0.120-in. wall tube brazed together.

Several specimens of tube-to-plug joints as shown on Fig. 1, sample 2, with the female member machined to 0.020-in. thick wall and some samples No. 4 were brazed under conditions of total time of brazing 5, 10, 15 and 30 min. In all of these tests, a perfect braze resulted. No variation was noted in the outside diameter of the female member during the brazing process as measured

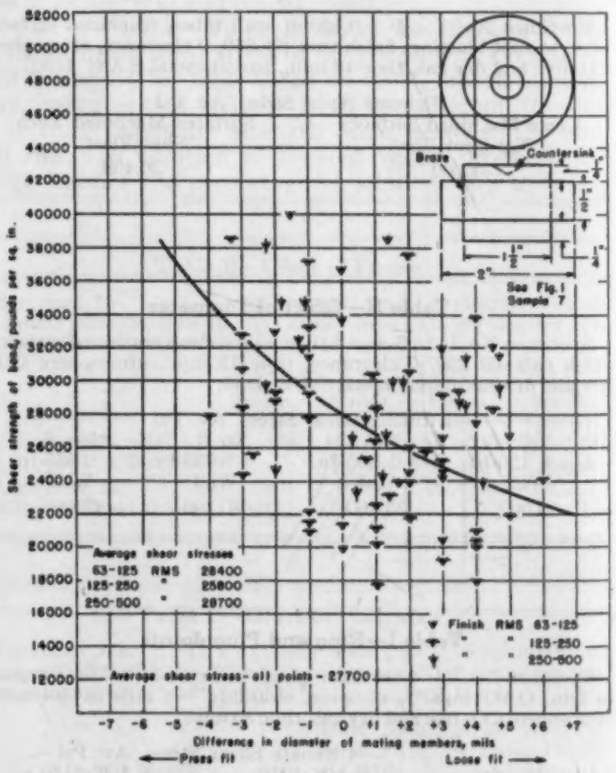


Fig. 6—Shear Strength of Bond vs. Clearance

Copper-brazed joints—S.A.E. 4130 steel ring and plug specimens, time 30 min., atmosphere CO_2-free and dry gas, machine finish below 500 rms., fillets removed, not heat treated.

Table N—Record of Failures

Miscellaneous joints, S.A.E. 4130 steel, clearances −4 mils to +4 mils, laps 3/16 to 7/16 in., atmosphere CO_2-free and dry gas.

Joint	Number Brazed	Number Failed to Braze
No. 3, 1/4- x 0.035-in.-wall machined	12	0
No. 5, 1- x 0.035-in.-wall machined	65	0
No. 6, 3- x 0.065-in.-wall machined	36	0
No. 8, tube and ring shot blast	25	
Nos. 9, 10, tube and ring machined	33	0
No. 2, tube and plug	9	0

before and after brazing. Sectioning indicated that the braze was completely sound. It was impossible to pull these samples as the thin-wall tube would invariably fail before the braze.

In addition, several machined female rings, 0.020-in. wall thickness, 1/2-long, were brazed to the male plug member shown in Fig. 1, specimen 2, for a brazing time of 12 min.; no shear-stress values were obtained since it was impossible to measure the strength, but in all cases the rings were perfectly brazed to the male member.

Incompletely Brazed Joints.—Five hundred seven samples were brazed with finishes below 500 rms. Eleven samples failed to braze 100%. This includes tubes and other types and all conditions of oxidized, oiled and sand-blasted surfaces.

Three hundred eight samples were brazed with finishes above 500 rms. One hundred thirty-nine failed to braze 100%. No samples other than 1- x 0.120-in. wall tubes were brazed in this range of finishes.

Tables K, L and M give the number of samples brazed in each group, the number of failures and the ultimate shear stress of the faulty joints.

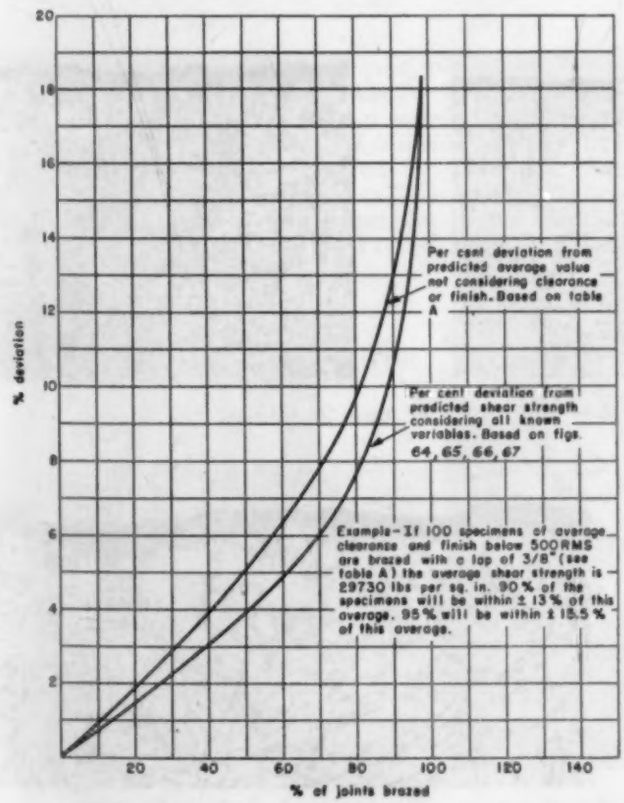

% deviation
% of joints brazed
Per cent deviation from predicted average value not considering clearance or finish. Based on table A
Per cent deviation from predicted shear strength considering all known variables. Based on figs. 64, 65, 66, 67
Example—If 100 specimens of average clearance and finish below 500 RMS are brazed with a lap of 3/8" (see table A) the average shear strength is 29730 lbs per sq. in. 90% of the specimens will be within ± 13% of this average. 95% will be within ± 15.5% of this average.

Fig. 7—Per Cent of Joints Brazed vs. Per Cent Deviation

Copper-brazed joints—1- x 0.120-in.-wall S.A.E. 4130 steel tubing, laps 3/16, 1/4, 5/16, 3/8 in., all clearances, time 12 min., atmosphere CO_2-free and dry gas, for all machine finishes, not heat treated.

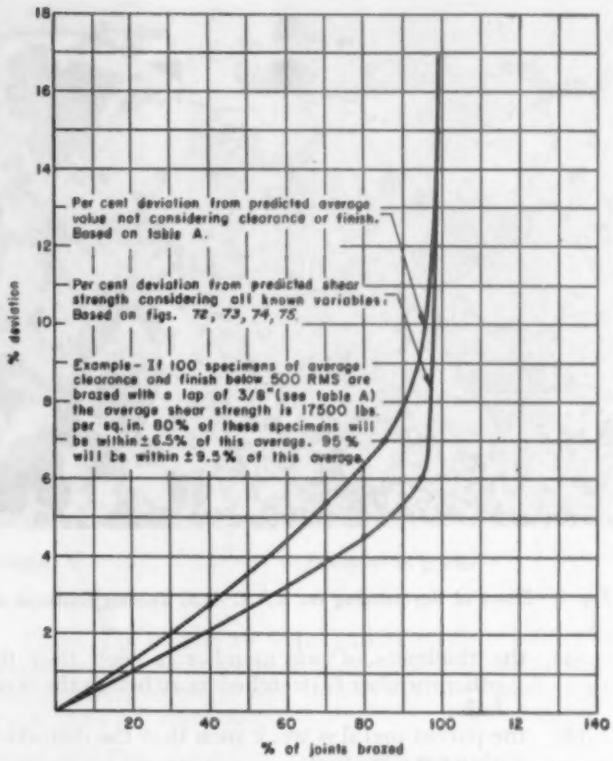

% deviation
% of joints brazed
Per cent deviation from predicted average value not considering clearance or finish. Based on table A.
Per cent deviation from predicted shear strength considering all known variables. Based on figs. 72, 73, 74, 75
Example—If 100 specimens of average clearance and finish below 500 RMS are brazed with a lap of 3/8" (see table A) the average shear strength is 17500 lbs. per sq. in. 80% of these specimens will be within ± 6.5% of this average. 95% will be within ± 9.5% of this average.

Fig. 8—Per Cent of Joints Brazed vs. Per Cent Deviation

Copper-brazed joints—1- x 0.120-in.-wall S.A.E. 1010 steel tubing, all clearances, all laps, time 12 min., atmosphere CO_2-free and dry gas, for all machine finishes, not heat treated.

Scatter of Data.—Figures 7 and 8 show the expected scatter of results of brazing several 1- x 0.120-in. wall tubes. This indicates that even if all known variables are considered, some particular joints will miss their predicted value by a wide margin. These curves are based on 1- x 0.120-in. wall tubes with a machined finish.

Decarburization.—Figure 9 shows comparison of surfaces of S.A.E. 4130 steel in the as-received condition and after normalizing.

Figure 10 shows the effect of the brazing atmosphere and temperature on the surface of 4130 steel free from decarburization before brazing when using two different atmospheres.

Figure 11 shows the final unmachined surfaces resulting from the as-received condition plus normalizing plus brazing for three different atmospheres.

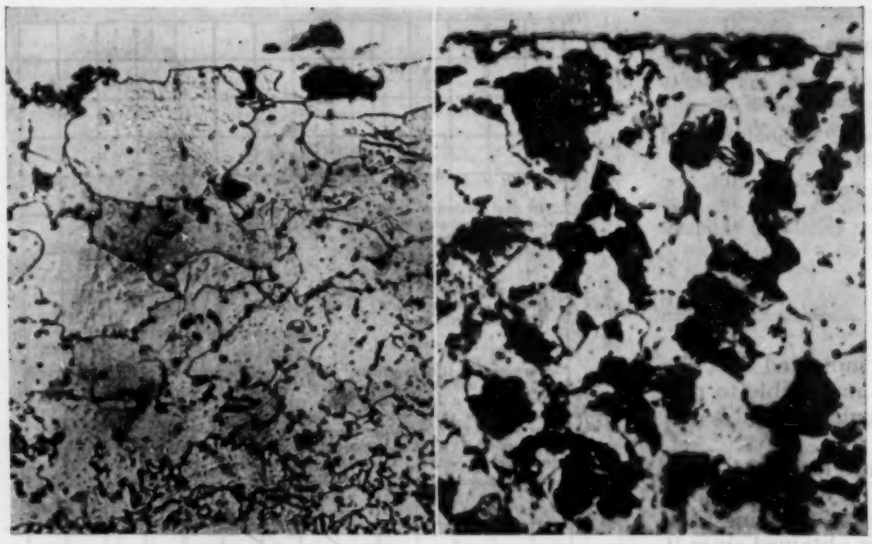
Nature of Bond.—Figures 12 and 13 show microstructure of bond for S.A.E. 1010 and S.A.E. 4130 steel showing copper iron alloy beginning to form.

Conclusions

Strength of Tube Joints

S.A.E. tube joints may be designed to fail at a stress above 30,000 psi. for a wide range of finishes, clearances, fits, diameters and wall thicknesses. The ultimate average shear stress of the bond, however, is determined primarily by the following factors in order of importance:

1. The deformation of the parent metal at time of failure of the bond, producing unequal shear stress in the bond and causing progressive failure. This concerns primarily the physical design of the joint. Lower average shear stress values will be encountered when,



Tubing as received — After normalizing

Fig. 9—Effect of Normalizing on S.A.E. 4130 Tubing Surfaces on Tube Exterior. ×500

(*a*) the thickness of one member is such that the other member is stretched more before the bond fails;

(*b*) the parent metal is weak such that the distortion above is increased;

(*c*) the lap is of such a value that the ultimate strength of the parent metal is approached as the bond fails;

(*d*) the joint is of such a design that necking down bending or flaring out occurs prior to failure of the bond;

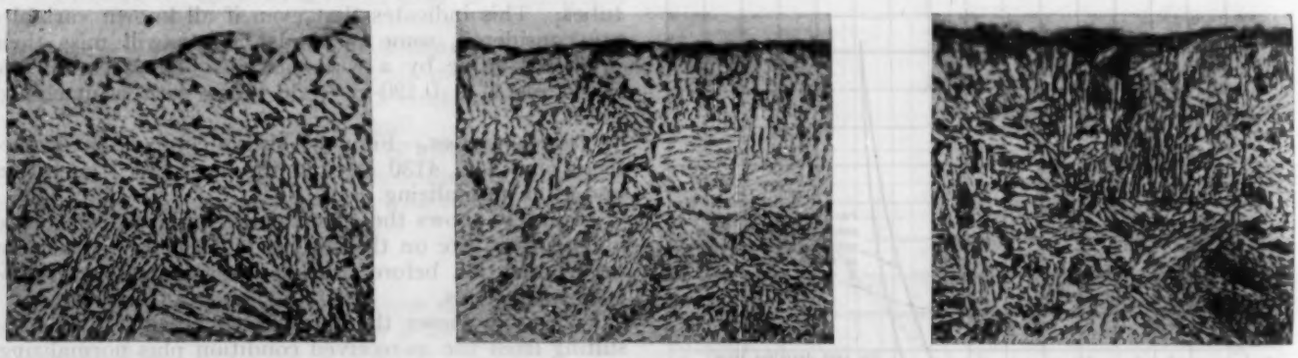
(*e*) the joint is large in diameter compared to the points remote from the joint at which tensile or compressive load is applied producing unequal stress in the bond around the periphery;

(*f*) the joint is such that the two members are axially misaligned and stress is not uniform around the periphery.

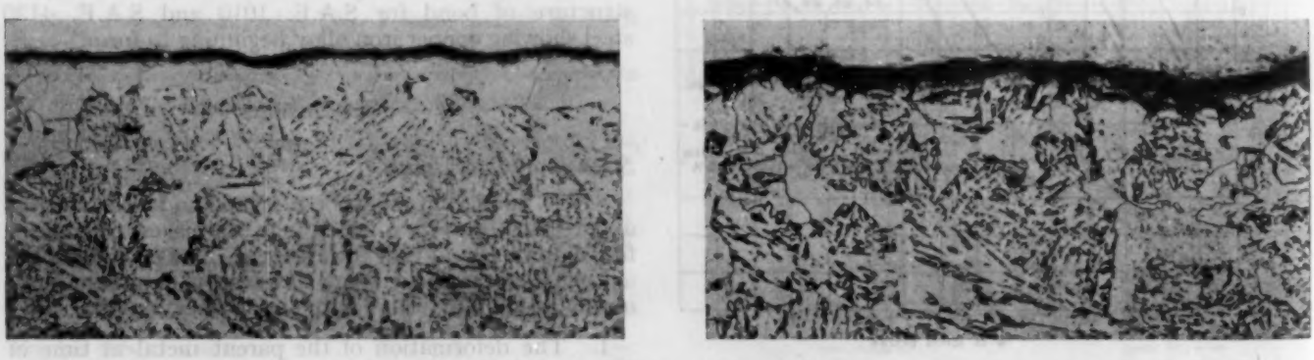
2. Surface finish and condition. The strength decreases from 100% at its optimum machined finish of 250–500 rms. to 89.4% for a machined finish of 500–1000 rms. or to 81% at a shot blast finish of 63–250 rms. or to 86.5% for a machined and oxidized surface of rms. 125–250 before brazing. However, within the range of machined finishes likely to be used (63–500 rms.) a decrease in strength from the optimum to worse condition will not cause a decrease in strength of more than 6%. Number 50 oil on the surface may decrease the strength 5.2%.

3. Time of brazing: Strength will decrease with insufficient time for alloying of the copper and steel. From a value of 100% at 24 min. (1- x 0.120-in. tubes) the strength may decrease to 92.8% for a time of 12 min.

4. Clearance between mating members: The strength may decrease from 100% at 5 mils per inch

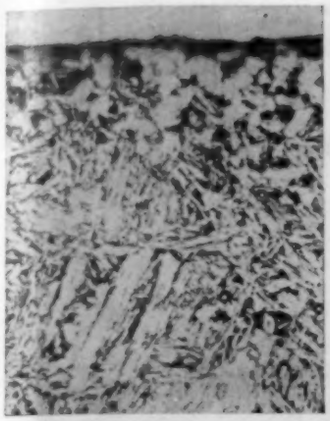


CO_2-free and dry gas atmosphere, dewpoint 0–10° F., time 24 min.

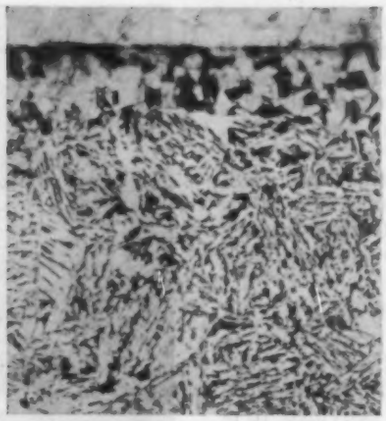


Partially combusted gas, time 24 min.

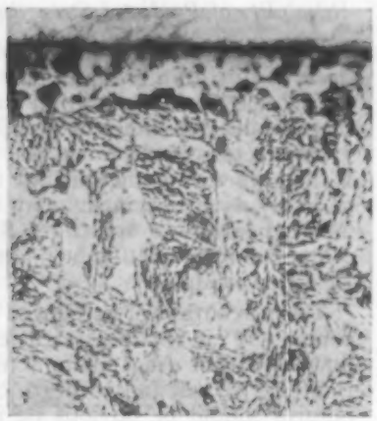
Fig. 10—Decarburization in Brazing Process on Surface Machined Prior to Brazing S.A.E. 4130 Tubing. 250×



S.A.E. 4130, drycolene atmosphere, brazing time 12 min.



S.A.E. 4130, CO_2-free and dry gas atmosphere, brazing time 12 min.



S.A.E. 4130, CO_2-free and dry gas atmosphere, brazing time 24 min.

Fig. 11—Typical Surfaces on Tube Interior After Being Brazed. 500×

Photomicrograph taken at points remote from copper flow. Surface condition is result of as-received condition and effect of brazing temperature.

(difference in diameter per inch) press fit to 95.9% for 5 mils per inch loose fit.

5. Atmosphere: A low hydrogen CO_2 and moisture-free mixture of CO and N_2 may have some advantage over a similar mixture with higher hydrogen to produce maximum strengths (1.6%). The high hydrogen CO_2 and moisture-free mixture may have an advantage over a similar mixture with moisture and CO_2 present (0.7%). The atmosphere with moisture and CO_2, however, is more injurious to the surface of the parent metal in causing decarburization.

Tube and Ring Joints

Based on these data, tube-to-ring joints must be designed with much lower ultimate stress values than tube-to-tube joints (below 8000 psi. for extremely thin rings). With a fixed tube dimension the ultimate average stress will increase with thickness of ring (or decreasing deformation of the ring as in tube-to-tube joints). Fillets left on the joint may add materially to the strength. The strength of this type of joint is also a function of the stress in the parent metal.

These low results to some extent confirm difficulties experienced in practice in brazing small male members to large female members and further investigations of this type joint are recommended.

Ring and Plug Joints

These data indicate that ring and plug joints of S.A.E. 4130 steel are stronger than tube-to-tube joints for press fits and lower for loose fits. Similar joints in S.A.E. 1010 steel are considerably stronger than tube-to-tube joints.

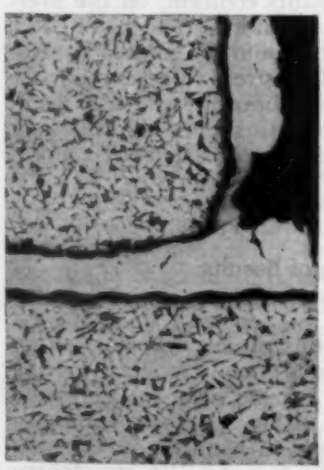
In these joints where rupture is caused by loading the male member in compression S.A.E. 1010 makes a stronger bond than S.A.E. 4130 (the reverse of tensile loaded tube-to-tube joints).

Surface finish and clearance have a more pronounced effect than for tube joints.

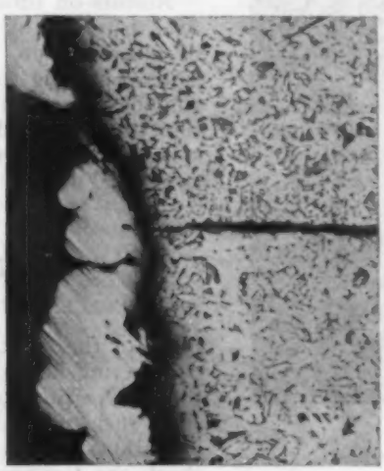
Fillets remaining on the joints after brazing materially increase the strength of the joint.

Tube-to-Plug Joints

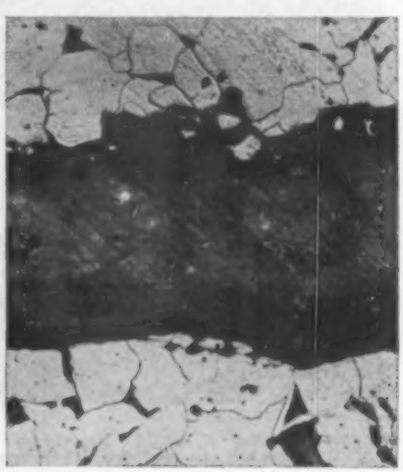
Tube-to-plug joints may give 14% greater strengths than similar tube-to-tube joints.



Inside fillet. 50×



Outside fillet. 50×



Bond. 500×

Fig. 12—S.A.E. 1010 Brazed Joints

Atmosphere CO_2-free and dry gas, time 12 min.

Reliability of Predicted Strengths

The strength of any given joint may not be predicted accurately. In a group of 100 well-brazed specimens as many as 11 may vary from their most accurately predicted value. As much as ±10% and 1 may vary ±20%. If the factors of clearance and finish are not considered in making the prediction but average values are used, as many as 19 specimens may vary as much as ±10%. These figures are based on S.A.E. 4130 tube-to-tube joints. S.A.E. 1010 tube joints more nearly approach their curve value.

The percentage of specimens brazed that do not bond completely is small. With clearances and machine finishes within usual manufacturing practices, not more than 2% should fail to braze completely. All of these failures should be obvious on inspection provided it is possible to place the copper on the joint in such a way that it will flow to a visible position after passing through the joint clearance.

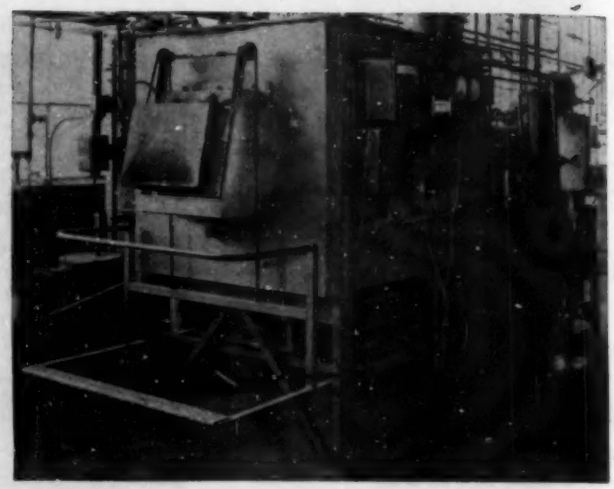
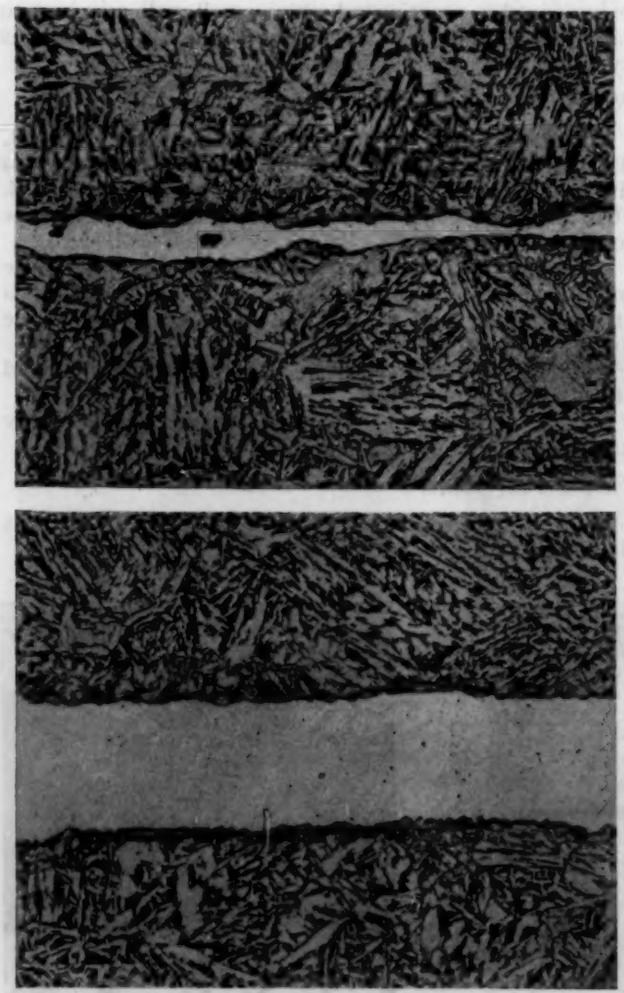


Fig. 14—Box Furnace in Which Samples Were Brazed

Bond between members on one sample with a tapered bore on the female member, 1/8 in. from inside fillet



Same sample as above, 1/8 in. from outside fillet.

Fig. 13—S.A.E. 4130 1- x 0.120-In.-Wall Tubing Brazed Joint. 250×

Atmosphere CO_2-free and dry gas, time 12 min.

Decarburization.—Commercial tubing is decarburized as received. This condition may be alleviated by a normalizing process prior to brazing with a slightly carburizing atmosphere.

S.A.E. 4130 steel may be brazed without any decarburization in a commercial atmosphere of CO, H_2 and N_2 regardless of the time required for brazing provided proper precautions are exercised to maintain a low moisture content of the atmosphere in the heating chamber (dew point below −10° F.).

Some decarburization must be expected in brazing S.A.E. 4130 steel in the above atmosphere with dew point of 0° F. (the maximum moisture content allowed in this investigation for "nondecarburizing" atmospheres).

Considerable decarburization must be expected regardless of how short the brazing cycle if a partially combusted gas atmosphere (containing CO_2 and H_2O) is used.

The amount of carbon loss in any atmosphere that will cause decarburization will increase with temperature, time, moisture CO_2 content and carbon content of the steel.

Comparison with Other Data

Results on tube-to-tube joints conform, on the average, to results by other investigators. The small effect of clearance on tube joints confirms general conclusions of brazing operators. Low stress values on tube-to-ring joints confirm difficulties on brazing small male members to large female members. Ring and plug values are somewhat lower than the maximum reported but conform to general data.

Discussion of Results

General

All of the work done on this project was done in an engineering development room—not a research laboratory. Operators doing the brazing were inexperienced shop men unfamiliar with either brazing or furnace operation. An attendant was on hand at all times to check the temperature of the furnace, the atmosphere in the furnace and to aid in the case of trouble, but the operators after brief instruction did the brazing. The method of brazing the furnace equipment and method of preparing samples were very similar to those which

would be encountered in any manufacturing plant. It should not be expected that a manufacturer doing considerable brazing would experience any more difficulties in these types of joints than were experienced in this investigation.

In only two instances was there any difficulty in causing the braze metal to fill the possible brazing area. In the case of 3-in. O.D. tubes, one lot was machined and was found to be considerably out of round after machining. Rather than scrap these tubes, it was decided to attempt to braze them, even though the clearances were not uniform around the periphery and the clearances varied considerably from the limits expected. Copper wire placed on the interior of the tube failed to completely fill the area. Copper wire on the outside of the tube did likewise.

Similar new samples were made up, normalized prior to machining and brazed by placing a single ring of copper wire on the outside and another on the inside of the joint. All of these tubes brazed 100%.

A considerable number of joints failed to braze 100% when the finishes were above 500 rms. The finishes used (approximately 1000 rms.) were considerably above that which would ever be experienced in practice and it is expected that these samples could have been satisfactorily brazed had enough copper been applied to the joint to completely fill all of the grooves in the machined members. Inspection of these joints after brazing eliminated approximately 44% of them from consideration as perfectly brazed joints and the remaining good joints failed at shear stress values 10% below the shear values expected for smoother finishes. It is probable, however, that the inspection after rupture failed to detect all of the samples that were not 100% brazed.

The general conclusion of this brazing project is that with any reasonable care in brazing any of the types of joints used, no difficulty whatsoever should be encountered in brazing a good joint with a reasonable shear strength. Reports of difficulty in brazing solid plug members to thin wall tube members and obtaining good brazes were investigated as part of this report. All of the samples brazed under these conditions were brazed 100% even though the time of brazing was varied considerably in an attempt to produce a poor braze.

Effect of Clearance

It was expected that the strength of the bond in the tube joints would vary materially as the clearance between the mating members was increased or decreased. This was not borne out by the tests. The literature on brazing indicates that the shear stress should increase materially as the fit is tightened and this has become a general axiom among people using copper brazing. However, in the case of tube-to-tube joints, there was very little, if any, indication of any change in average shear stress for zero clearances and 4 mils press fit.

The probable explanation of this is that although the fit may be pressed prior to brazing, at the time of brazing, the strains of the material are completely relieved and the weaker member is allowed to move in such a manner that there is no stress between the members. Although the fit may be 4 mils press before brazing, at the time of brazing it is zero clearance or slightly larger. Evidence to substantiate this can be obtained by checking the outer diameter of a press fit male member after rupture and noting that there is a thickness of copper film on the surface of the member, although the clearance should be, of course, zero. Examination of photomicrographs of such a sample show that the copper is actually added to the surface, indicating that there has been some clearance at the time of brazing. Further evidence to substantiate this is a consideration of the ring and plug specimens. In these specimens there is a much greater change in ultimate shear stress with clearance, giving higher values of shear strength as would be expected at the higher press fits. In these members the outer and inner members were substantial enough to maintain their relationship even in the heat. This does not lead to the conclusion that there is no advantage in using press fits. The principal advantage of using press fit is in maintaining alignment of the parts to be brazed during the brazing process. Great difficulty was experienced in brazing all of the loose members to prevent the deviation of the axis of one member from the axis of another, and in the case of a large number of members the results cannot be considered because of the extent of this misalignment. In the case of the extreme loose fits, it was almost impossible to determine the lap in advance that would be obtained after brazing as the tubes were free to move around in the furnace as the tray was moved into the heating chamber and into the cooling chamber. In the case of ring and plug members, it was necessary to stake the members to prevent the female member coming from the shaft during heating.

Furthermore, in the case of loose joints, it is more difficult to have the copper completely fill the possible brazing volume. In such members there is always the possibility of copper covering only one-half of the circumference of the member and the other half being left void of copper.

Effect of Finish

Investigations by some of the aircraft companies indicate that there should be an optimum finish at approximately the same values arrived at in this report, although their tests were done on ring and plug samples rather than on tube-to-tube joints. On tube-to-tube joints, it is noticed that the finish is not nearly as appreciable a factor as in the ring and plug specimens and, in fact, may be almost neglected. It is expected that any optimum value of finish arrived at for tube-to-tube samples would be affected materially by the length of the heating time, the types of joints and the clearance of fit.

The lower values of shear strength for the extremely smooth surface finishes as reported by some of the aircraft manufacturers may be due to the fact that the copper will not properly wet the smoother surfaces and the number of voids in the joints may be extremely large. It is not known whether these original specimens were actually completely brazed, as in the case of all samples considered in comparing surface finish in this report.

Most of the work done by the aircraft companies in comparing surface finish has been on finishes that were ground smooth and shot blasted with different sized shots. It should be noted that the production of the finish on the surface by means of any of the latter two methods does not necessarily prevent the flow of copper through the joint, whereas roughening of the surface by cutting machine scratches deeper tends to prohibit the flow of copper perpendicular to the scratches.

It should be pointed out that the rms. values of machine finish are only comparative for the machine finishes and that it is impossible to duplicate surface finishes merely by holding the same rms. number. An rms. finish may be obtained by any of several machined methods and be entirely different in character and may have different optimum values of finishes for maximum strength.

Effect of Lap

Most of the data and literature on strength of copper-brazed joints fails to consider the effect of the overlap area. In this project it was hoped and expected that a

joint of twice the overlap in inches would have twice the strength and that it would not be necessary to test a wide variety of laps. However, it will be noted from Table A that the most predominant variable in the entire project proved to be the amount of lap. It is not believed that the actual lap has any effect on the actual strength of the bond, but has an effect on causing a distribution of stresses in the bond such that progressive failure is encountered and the average strength is much lower. On the 4130 tube joint, very little deformation of the tubes with small laps could be noted after rupture. On the larger lap it was noted that the female tube had tended to bell out and its end showed a slight increase in diameter. This effect was very noticeable on the S.A.E. 1010 steel and on the larger laps the diameter may have been increased $^1/_8$ in. at failure.

This is further confirmed by the fact that, although bonds in S.A.E. 1010 tube joints with lower ultimate tensile strengths then S.A.E. 4130 give low ultimate shear values, this is not true of ring and plug joints. (In ring and plug joints strengths were actually greater for the S.A.E. 1010 steel.)

This phenomenon means that if the designer intends that the parent metal and the tube should fail simultaneously (that is, if he expects to obtain the maximum conservation of weight or machining of copper from a brazed joint) it is necessary that he design on the basis of the lower ultimate shear stress which occurs at values of thickness and lap and tensile strength of the parent metal to produce the ultimate tensile stress in the steel.

Effect of Atmosphere

The comparisons between the three furnace atmospheres which show no appreciable change in strength between them do not necessarily indicate that neither of the atmospheres is advantageous over the others. All the samples considered were 100% brazed. The results, therefore, only indicate that if the copper completely fills the possible bond area between the members for the joint considered and in the time considered, there is no advantage in strength in using any of the atmospheres. It has been generally thought, however, that atmospheres with high hydrogen aid the flow of copper by being more reducing than the low-hydrogen atmospheres. There is good evidence to believe, therefore, that either the carbon dioxide-free and dry gas or the partially combusted gas might show advantage in brazing particular steels.

The effect of the atmosphere in decarburizing, however, is of marked interest. It has been known that partially combusted gas undried and without CO_2 removal, is a harmful decarburizer. Until recently, however, most of the brazing has been done in this partially combusted gas which is completely satisfactory for brazing low-carbon steels or parts where the time of brazing is short and slight decarburization of the surface is not of importance. Some tests by the author in the past have indicated that there is little difference in the decarburization rate at brazing temperatures between the atmosphere carbon dioxide-free and dry gas and "Drycolene," provided the dew points are maintained at approximately the same value. These tests have also indicated that for brazing a steel of this carbon content in practice, it is necessary that an atmosphere be maintained in the furnace with a furnace dew point of less than minus 10° F.

Effect of Time

The slight increase in strength of the bond with an increase in brazing time is probably due to an increase in the extent of alloying of the parent metal.

Effect of Size of Tube

Comparison of strength data on Table H, shows that the $^1/_4$-in. diam. tubes, the 1-in. diam. tubes and the 3-in. diam. tubes have decreasing strengths as their diameter increases. An interpretation of these results strictly on the basis of diameter, however, is erroneous. The high value of the $^1/_4$-in. diam. tubes is attributed to the large percentage of copper that remains in the fillet, compared to the bond area of the joints and to the high ratio of length to diameter causing more equal stress distribution. It is impossible to remove the inside fillet from these joints, and in order to have the braze fail in the bond rather than in the tube it was necessary that the overlap be extremely small (approximately $^1/_8$ in.). The erratic results obtained on the $^1/_4$-in. diam. tubes, the 1- x 0.120-in. wall thin tubes and the 3-in. tubes may be attributed to the small lap necessary to cause the tube to fail in the bond. The extremely low values of the 3-in. diam. tubes is attributed to the fact that failure occurred simultaneously in the tube and in the braze itself. First examination of these specimens lead to the conclusion that all of the tubes failed in the parent metal. Further examination showed that the failure was approximately simultaneous in both, and which preceded the other it was impossible to determine. It was noted, however, that in general the tube failed in the bond on one-half of the circumference and failed in the tube on the other half, indicating that with such a large-diameter, short thin-wall tubes, the stress distribution in loading may have been concentrated to a great extent on one side or the other of the specimens. It is reasonable to expect that with large-diameter long tubes, approximately the same results could be obtained in psi. shear as with 1-in. x 0.120-in. wall tube.

Tube and Plug Joints

The highest shear values for any tube joints were obtained when a 1-in. diam. x 0.120-in. wall female member was brazed to a solid plug male member. This particular joint had all of the advantages of correct stress distribution and thickness of parent metal not obtained in any of the other samples. Since the specimen was as long as the tube-to-tube joint, the stress distribution should be as good as those and since the male member was a solid member rather than a tube, it should not tend to contract upon loading in tension. We might rightly expect this sample to give the results obtained.

Tube-to-Plate Joints

The low values as indicated on Fig. 5 for tube-to-plate joints were very disappointing. Although we might attempt an explanation for this, the case will merit some further study. It should be noted that in the samples, the length of specimen was one-half that of the others and the distribution of stress around the braze at the time of the failure could be expected to be much worse than in the case of any of the tube joints. Since the ultimate stresses were greater for the thicker rings, it might be an indication that the stress in the bending of the ring has the same kind of effect as the stress in tension on the tube joints. It should be noted that these rings were pulled in tension rather than in compression.

It should also be noted that the strengths are materially increased at the lower thicknesses of the ring by the presence of a fillet.

Ring and Plug Joints

The results of the ring and plug samples were the most inconsistent of any of the data with the exception of the large-diameter tubes. The first samples brazed did not

have a countersink on the solid male member and the sample was loaded by simply pushing out the inner disk in the testing machine. The results on this were erratic and less in value than the tube joints. Further groups of samples were machined with a countersink and the female member placed in a hardened die and the ball placed in the countersink, and the force applied to the top of the ball. Even this procedure did not eliminate the scatter of data. Successive batches of samples made and tested failed to improve this. The original assumption that the surface finish had little to do with the strength of the joint did not bear itself out with the ring and plug joints and it was necessary to more closely control the finish. However, this did not explain the situation and the final interpretation is that in such a joint the stress distribution is too nonuniform to obtain the maximum strength from the copper bond based on average area of the bond.

It is also interesting to note that the condition of optimum surface finishes reversed for the ring and plug samples as compared to the tube to tube specimens. It should also be noted that the 1010 samples show greater strength than the 4130 samples for the ring and plug joints although this was directly opposite in the case of the tube to tube specimens.

No explanation can be made for the difference in effect of surface finish on these two joints but it is the feeling of the author that many more tests would have to be conducted to adequately establish the difference reported here.

An explanation for the increased strength of the S.A.E.-1010 steel may be derived from examination of the manner in which the specimen failed. It should be noted that the ring and plug samples failed in compression and in the case of the lower strength materials there is a definite deformation of the inner member forcing itself outward into the ring as pressure is applied. This tends to increase the pressure between the two joints and, therefore, to a certain extent increase the apparent shear stress of bond. In the case of the tube joints this was just the opposite and failure of the tubes in tension was preceded by a necking down of the tube to some extent such that the pressure between the joints tended to decrease as failure occurred. The 4130 steel being stronger than the 1010 would naturally tend to resist this deformation in the bond in either case, tending to cause a greater strength on the tube joints than on the ring and plug joints.

The increased strength of the members with fillets was surprising. The fillets in this particular case were rather large as in all cases adequate copper had been applied to the joints to completely fill even the loose members but the increased area provided in the copper bond by the fillet is not in proportion to the increase in strength. It is unfortunate that enough samples were not investigated to adequately establish the value of the fillet.

Effects of Misalignment

An attempt was made on the first lot of tube-to-tube samples brazed to establish some criterion for the effects of misalignment on the shear strength. These curves indicated that while the scatter of the data increased considerably as the misalignment increased, particularly in the case of the loose fits, no adequate tabulation could be shown to show the effect of the mount of misalignment on the strength of the joint. In all cases, with increasing laps, the results were more consistent than those with the small laps. In the case of the larger laps, most of the samples were more nearly correctly aligned and the possibility of unequal stress distribution was lessened. Throughout this investigation, however, in every instance, a large percentage of the scatter of the data can be attributed to the actual dimensions of the samples themselves and their position in the testing machine. It is recommended that if further work be done on tube-to-tube or ring and plug samples, some means be devised for providing less misalignment in the specimens. All samples should be longer and spaced further between the jaws of the testing machine in order that the stress may be more nearly uniform in the bonded area.

The effects of the design of the joint itself and the probable misalignment in actual loading in practice lead to the conclusion that further tests should be made in which the specimens would stress in some method other than tension, perhaps in bending. Slight eccentric loads applied to the joints might be the controlling factor in the design of the joint rather than in tension as is only covered in this report.

1946 YEAR BOOK
AMERICAN WELDING SOCIETY

A limited supply printed. Available to members without charge upon request. Address American Welding Society, 33 West 39th Street, New York 18, N. Y.

Standard Welding Symbols

Notice to Members of American Welding Society:

The standard reproduced herein has not been approved by the AMERICAN WELDING SOCIETY. It was prepared by the A.W.S. Committee on Symbols as a proposed revision of the SOCIETY's standard entitled *Welding Symbols and Instructions for Their Use*, and is being published for the purpose of eliciting comments, criticisms and suggestions. After such criticisms are received, it is the intention of the Committee to make such changes in the standard as seem desirable, following which the standard will be submitted for approval and publication as a full standard of the AMERICAN WELDING SOCIETY.

This revision consists principally of an editorial rewording and rearrangement, intended to clarify the text and make it simpler for the average user to comprehend. Many illustrations have been added to order to provide specific examples of the use of the symbols under a wide variety of applications.

There are two principal changes that have been incorporated in this proposed revision. The first relates to the weld symbol used to denote a square-groove weld made by arc or gas welding. In the present *Welding Symbols and Instructions for Their Use*, this symbol is a single vertical line and is exactly the same as the symbol used to denote a resistance butt weld. In the proposed standard the symbol for the square-groove weld made by arc or gas welding consists of two parallel vertical lines, as shown in Fig. 1 and as illustrated more fully in Fig. 8. The symbol for a flash or upset weld (resistance butt weld) has been retained without change, thus removing any possibility of confusion between arc or gas welds and resistance welds.

The second important change relates to designating the size of groove welds made by those processes which produce appreciable penetration into the root of the joint. With these deep-penetrating processes (e.g., submerged melt welding) the size of the weld exceeds the depth of the grooving. Under the existing system these welds can be fully dimensioned only by means of a sketch or other detail, with a reference thereto in the tail or on the reference line of the welding symbol. In the proposed standard, however, means are provided in Article 503 for placing complete dimensional information on the symbol itself.

All comments on this proposed standard will be greatly appreciated. They should be forwarded not later than Sept. 1, 1946, and should be addressed to the Secretary, Committee on Symbols, American Welding Society, 33 West 39th Street, New York 18, N. Y.

FOREWORD

Welding cannot take its proper place as an engineering tool unless means are provided for conveying the information from the designer to the workmen. Such practices as writing "To be welded throughout" or "To be completely welded" on a drawing, in effect transfer the design of all attachments and connections from the designer to the welding operator, who cannot be expected to know what strength is necessary. This practice, in addition to being dangerous, may also be costly, for certain shops in their desire to be safe use much more welding than is necessary.

These symbols provide the means of placing complete welding information on drawings. In practice many companies will probably need only a few of the symbols, and if they desire, can select such parts of the scheme as fit their needs and ignore the others. If this is done universally, all will be speaking the same language even though some use but a few of the symbols contained herein.

The use of the words "far side" and "near side" in the past has led to confusion because when joints are shown in section, all welds are equally distant from the reader and the words "near" and "far" are meaningless. In the present system the *joint* is the basis of reference. Any joint the welding of which is indicated by a symbol will always have an "arrow side" and an "other side". Accordingly, the words "arrow side," "other side" and "both sides" are used herein to locate the weld with respect to the *joint*.

Appropriate finish marks have been found to be necessary. However, recommendations as to what finish marks shall be used are not strictly within the province of this SOCIETY. When the American Standards Association adopts a system of finish symbols, it will be desirable for all concerned to use that system.

The tail of the symbol is used for designating the welding specifications, procedures or other supplementary information to be used in the making of the weld. If a welding operator knows the size and type of weld, he has only part of the information necessary for making that weld. The process, identification of filler metal that is to be used, whether or not peening or root chipping are required, and other pertinent data must be known. The notation to be placed in the tail of the symbol indicating these data will usually be established by each user. If notations are not used, the tail of the symbols may be omitted.

STANDARD WELDING SYMBOLS

SECTION I—BASIC SYMBOLS

101. Arc and Gas Weld Symbols

Arc and gas weld symbols shall be as shown in Fig. 1.

BASIC ARC AND GAS WELD SYMBOLS							
TYPE OF WELD							
BEAD	FILLET	PLUG OR SLOT	GROOVE				
			SQUARE	V	BEVEL	U	J
⌒	◺	▱	‖	V	◸	Y	⌡

FIG. 1

102. Resistance Weld Symbols

Resistance weld symbols shall be as shown in Fig. 2.

103. Brazing Symbols

Brazing shall be indicated by using a process or specification reference in the tail of the welding symbol. (See Article 303.)

BASIC RESISTANCE WELD SYMBOLS			
TYPE OF WELD			
SPOT	PROJECTION	SEAM	FLASH OR UPSET
✳	⟋⟍	XXX	|

FIG. 2

104. Supplementary Symbols

Supplementary symbols to be used in connection with arc, gas and resistance weld symbols shall be as shown in Fig. 3.

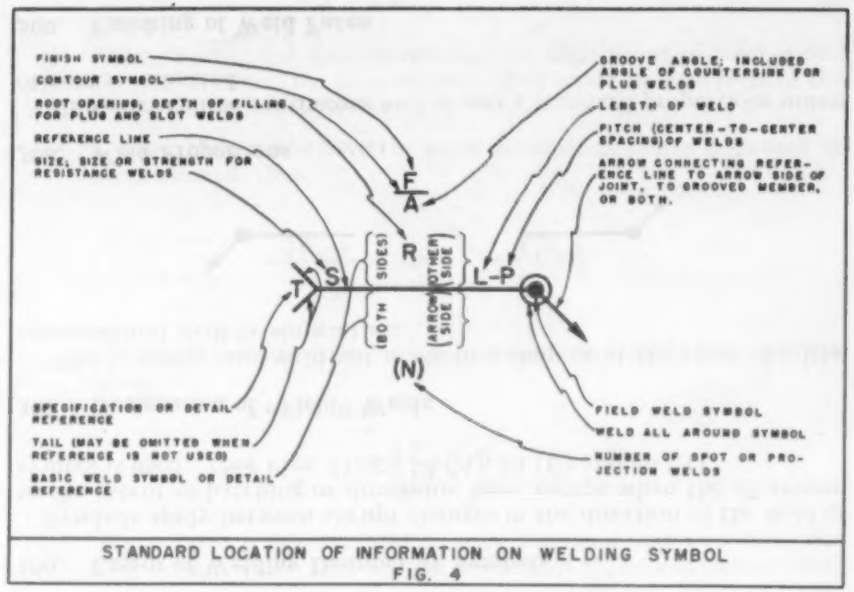
SUPPLEMENTARY SYMBOLS			
WELD ALL AROUND	FIELD WELD	CONTOUR	
		FLUSH	CONVEX
○	●	—	⌒

FIG. 3

105. Elements of a Welding Symbol

The assembled welding symbol consists of the following eight elements. Such of these elements as are necessary shall be used and these elements shall have standard locations with respect to each other as shown in Fig. 4.

Reference line.
Arrow.
Basic weld symbol.
Supplementary symbol.
Tail.
Dimensions and other data.
Finish symbol.
Specification or other reference.


FINISH SYMBOL
CONTOUR SYMBOL
ROOT OPENING, DEPTH OF FILLING FOR PLUG AND SLOT WELDS
REFERENCE LINE
SIZE, SIZE OR STRENGTH FOR RESISTANCE WELDS
GROOVE ANGLE; INCLUDED ANGLE OF COUNTERSINK FOR PLUG WELDS
LENGTH OF WELD
PITCH (CENTER-TO-CENTER SPACING) OF WELDS
ARROW CONNECTING REFERENCE LINE TO ARROW SIDE OF JOINT, TO GROOVED MEMBER, OR BOTH.
F
A
R
L-P
T
S
(BOTH SIDES)
(ARROW SIDE / OTHER SIDE)
(N)
SPECIFICATION OR DETAIL REFERENCE
TAIL (MAY BE OMITTED WHEN REFERENCE IS NOT USED)
BASIC WELD SYMBOL OR DETAIL REFERENCE
FIELD WELD SYMBOL
WELD ALL AROUND SYMBOL
NUMBER OF SPOT OR PROJECTION WELDS

STANDARD LOCATION OF INFORMATION ON WELDING SYMBOL
FIG. 4

SECTION II—BASIC JOINTS AND WELDS

201. Basic Joints

The basic types of joints are shown in Fig. 5 and the types of welds by which the members are frequently joined are listed thereon.

202. Basic Welds

The basic types of welds indicated by the basic weld symbols are illustrated in Figs. 6 to 17, inclusive.

SECTION III—GENERAL PROVISIONS

301. Method of Drawing Symbols

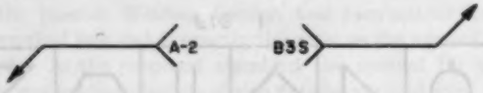
Symbols may be made freehand or not, as desired.

302. Use of Inch, Degree and Pound Marks

Inch, degree and pound marks may be used on welding symbols or not, as desired, except that inch marks shall be used for indicating the diameter of spot or projection welds, and the width of seam welds.

303. Location of Specification or Process Reference

When a specification or process reference is used with a symbol, the reference shall be placed in the tail, thus:



304. Use of Symbols Without Specification References

When desired, symbols may be used without specification references in the following instances:

(*a*) When a note such as the following appears on the drawing: "Unless otherwise designated, all welds are to be made in accordance with Welding Specification No. —."
(*b*) When the welding procedure to be used is prescribed elsewhere.

305. Use of General Notes

When desired, general notes such as the following may be placed on a drawing to provide detailed information pertaining to the predominating welds, and this information need not be repeated on the symbols.

"Unless otherwise indicated, all fillet welds are $^{5}/_{16}$ inch size."
"Unless otherwise indicated, root openings for all groove welds are $^{3}/_{16}$ inch (plus $^{1}/_{8}$ minus 0)."

306. Extent of Welding Denoted by Symbols

Symbols apply between abrupt changes in the direction of the weld or to the extent of hatching or dimension lines, except when the all-around symbol is used. (See Figs. 21, 22, 33 (*A*), 34 (*C*) and 36 (*A*).

307. Designation of "Field" Welds

"Field" welds (any weld not made in a shop or at the place of initial construction) shall be shown thus:

308. Weld Proportions

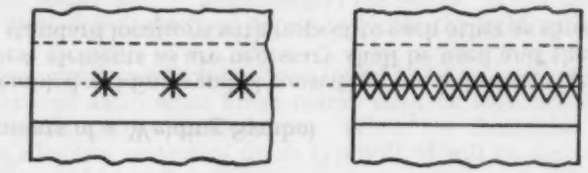
All welds shall be continuous and of user's standard proportions unless otherwise indicated.

309. Finishing of Weld Faces

Faces of welds shall not be finished other than cleaned unless otherwise indicated.

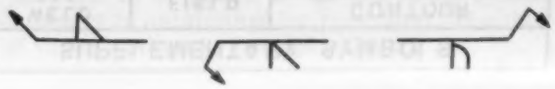
310. Location of Weld Symbols

(*a*) Weld symbols, except spot and seam weld symbols, shall be shown only on the reference line and not on the lines of the drawing.
(*b*) Spot and seam weld symbols may be used directly on drawings, thus: (See also Fig. 15.)



311. Construction of Fillet, Bevel- and J-Groove Weld Symbols

Fillet, bevel- and J-groove weld symbols shall be shown with the perpendicular leg *always* to the left, thus: (See also Figs. 6, 7, 9 and 11.)



312. Location of Information on Welding Symbols

Information on welding symbols shall be placed to read from left to right along the reference line in accordance with standard drawing room practice, thus:

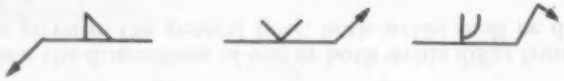
313. Use of Break in Arrow for Bevel- and J-Groove Welds

When a bevel- or J-groove weld symbol is used, the arrow shall point with a definite break toward the member which is to be grooved, thus: (See also Figs. 9 and 11.)

314. Location of Weld with Respect to Joint

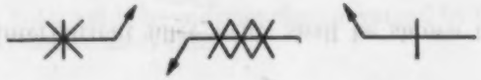
(*a*) Welds on the arrow side of the joint shall be shown by placing the weld symbol on the side of the reference line toward the reader, thus: (See also Figs. 6 (*A*), 8 (*A*), 9 (*A*), 10 (*A*), 11 (*A*), 12 (*A*), 13 (*A*), 14 (*A*) and 16 (*A*).)

(*b*) Welds on the other side of the joint shall be shown by placing the weld symbol on the side of the reference line away from the reader, thus: (See also Figs. 6 (*B*), 8 (*B*), 9 (*B*), 10 (*B*), 11 (*B*), 12 (*B*), 13 (*B*), 14 (*B*) and 16 (*B*).)



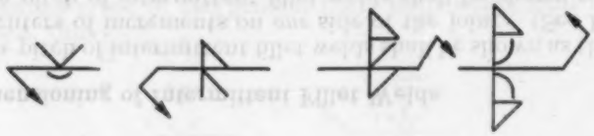
(*c*) Welds on both sides of the joint shall be shown by placing the weld symbols on both sides of the reference line, toward and away from the reader, thus: (See also Figs. 7, 8 (*C*), 9 (*C*), 10 (*C*), 11 (*C*) and 12 (*C*).)

(*d*) Spot, seam, flash and upset weld symbols have no arrow-side or otherside significance. These symbols shall be centered on the reference line, thus: (See also Figs. 15 and 17.)



315. Combined Welds

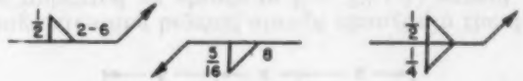
For joints having more than one weld, a symbol shall be shown for each weld, thus: (See also Figs. 18 and 25.)



SECTION IV—DIMENSIONING OF FILLET WELDS

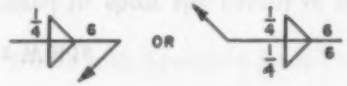
401. General

(*a*) Dimensions of fillet welds shall be shown on the same side of the reference line as the weld symbol, thus: (See also Figs. 19, 20 and 21.)

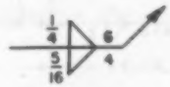


(*b*) When no general note governing the dimensions of fillet welds appears on the drawing, the dimensions of fillet welds on both sides of the joint shall be shown as follows:

(1) When both welds have the same dimensions, one or both may be dimensioned, thus:



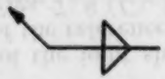
(2) When the welds differ in dimensions, both shall be dimensioned, thus:



(*c*) When there appears on the drawing a general note governing the dimensions of fillet welds, such as "All fillet welds 5/16 in. size unless other-

wise noted," the dimensions of fillet welds on both sides of the joint shall be shown as follows:

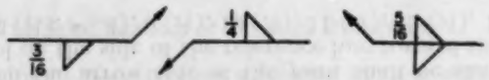
(1) When both welds have dimensions governed by the note, neither need be dimensioned, thus:



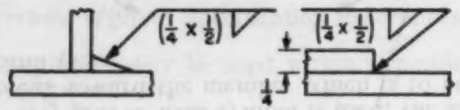
(2) When the dimensions of one or both welds differ from the dimensions given in the general note, both welds shall be dimensioned, thus:

402. Size of Fillet Welds

(*a*) The size of a fillet weld shall be shown to the left of the weld symbol, thus: (See also Figs. 19 (*A*), 19 (*B*), 19 (*C*) and 19 (*D*).)

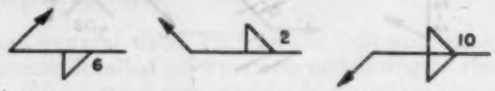


(*b*) The size of a fillet weld with unequal legs, shall be shown in parentheses to the left of the weld symbol, as shown below. Weld orientation is not shown by the symbol and shall be shown on the drawing when necessary. (See also Fig. 19 (*D*).)



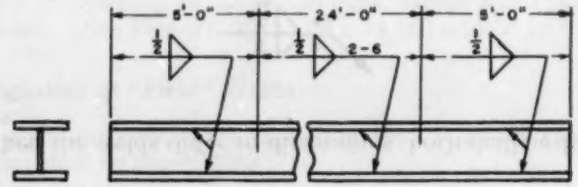
403. Length of Fillet Welds

(*a*) The length of fillet welds shall be shown to the right of the weld symbol, thus: (See also Fig. 19 (*F*).)

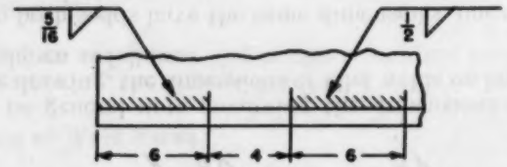


(*b*) When a fillet weld extends for the full length of the joint, no length dimension need be shown on the welding symbol. (See Fig. 19 (*E*).)

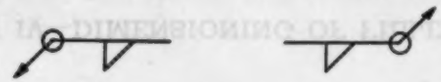
(*c*) Specific length of welds may be indicated by symbols in conjunction with dimension lines, thus: (See also Figs. 21 (*A*) and 21 (*B*).)



404. Extent of Fillet Welds

(*a*) When it is desired to show the extent of welds graphically, one type of hatching with definite end lines shall be used, thus:

(*b*) Welding extending beyond abrupt changes in the direction of the weld shall be indicated as shown in Fig. 22 (*A*) except when the all-around symbol is used.

(*c*) All-around fillet welds (welds encircling the joint in so far as possible) shall be shown by means of the all-around symbol, thus: (See also Fig. 22 (*B*).)



405. Dimensioning of Intermittent Fillet Welds

(*a*) The pitch of intermittent fillet welds shall be shown as the distance between centers of increments on *one* side of the joint. (See Fig. 20.)

(*b*) The pitch of intermittent fillet welds shall be shown to the right of the length dimension, thus: (See also Fig. 20.)

(*c*) Chain intermittent fillet welds shall be shown thus: (See also Fig. 20 (*B*).)

(*d*) Staggered intermittent fillet welds shall be shown thus: (See also Fig. 20 (*C*).)

406. Termination of Intermittent Fillet Welding

(*a*) When intermittent fillet welding is used by itself, the symbol indicates that increments shall be located at the ends of the dimensioned length. (See Fig. 20.)

(*b*) When intermittent fillet welding is used between other welding, the symbol indicates that spaces shall be placed at the ends of the dimensioned length. (See Fig. 21 (*A*).)

407. Combinations of Continuous and Intermittent Fillet Welds

A separate welding symbol for each weld shall be used when intermittent and continuous fillet welds are used in combination. (See Fig. 21 (*A*).)

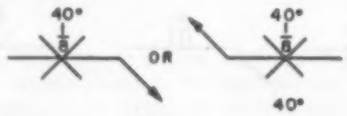
SECTION V—DIMENSIONING OF GROOVE WELDS

501. General

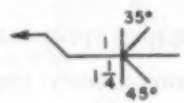
(*a*) Dimensions of groove welds shall be shown on the same side of the reference line as the weld symbol, thus: (See also Fig. 29 (*B*).)

(*b*) When no general note governing the dimensions of groove welds appears on the drawing, the dimensions of double-groove welds shall be shown as follows:

(1) When both welds have the same dimensions, one or both may be dimensioned, thus:

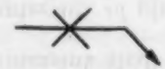


(2) When the welds differ in dimensions, both shall be dimensioned, thus:



(*c*) When there appears on the drawing a general note governing the dimensions of groove welds, such as "All V-groove welds shall have a 60° groove angle unless otherwise noted," the dimensions of double-groove welds shall be shown as follows:

(1) When both welds have dimensions governed by the note, neither need be dimensioned, thus:



(2) When the dimensions of one or both welds differ from the dimensions given in the general note, both welds shall be dimensioned, thus:

(*d*) The size of a groove weld shall be shown to the left of the weld symbol, thus: (See also Fig. 23.)

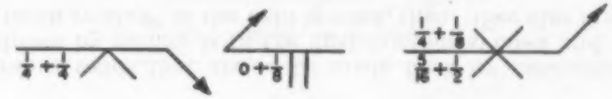
502. Size of Groove Welds with No Specified Root Penetration

(*a*) The size of single-groove and symmetrical double-groove welds which extend completely through the member or members being joined, need not be shown on the welding symbol. (See Figs. 23 (*D*) and 23 (*E*).)

(*b*) The size of groove welds which extend only partly through the member or members being joined, shall be shown on the welding symbol. (See Figs. 23 (*A*), 23 (*C*) and 23 (*F*).)

503. Size of Groove Welds with Specified Root Penetration

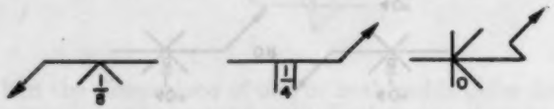
The size of groove welds with specified root penetration shall be indicated by showing both the depth of grooving and the root penetration, separated by a plus mark and placed to the left of the weld symbol. The depth of grooving and the root penetration shall read in that order from left to right along the reference line, thus: (See also Figs. 24 and 25.)



504. Details of Groove Welds (Groove Dimensions)

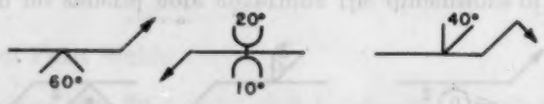
(*a*) Root opening of groove welds shall be the user's standard unless otherwise indicated.

(*b*) Root opening of groove welds, when not the user's standard, shall be shown inside the weld symbol, thus: (See also Fig. 26.)



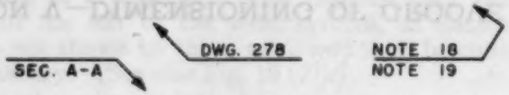
(*c*) Groove angle of groove welds shall be the user's standard, unless otherwise indicated.

(*d*) Groove angle of groove welds, when not the user's standard, shall be shown thus: (See also Fig. 27.)



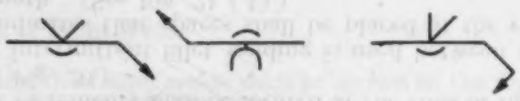
(*e*) Groove radii and root faces of U- and J-groove welds shall be the user's standard unless otherwise indicated.

(*f*) When groove radii and root faces of U- and J-groove welds are not the user's standard, the weld shall be shown by a cross section, detail or other data, with a reference thereto on the welding symbol, observing the usual location significance, thus:



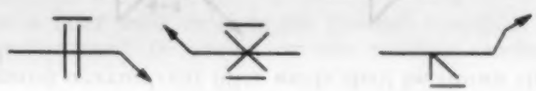
505. Designation of Back and Backing Beads

Back and backing beads of single-groove welds shall be shown with the bead weld symbol, thus:

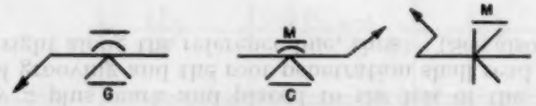


506. Surface Contour of Groove Welds

(*a*) Groove welds that are to be welded flush without recourse to any method of finishing shall be shown by adding the flush-contour symbol to the weld symbol, thus: (See also Fig. 28 (*A*).)



(*b*) Groove welds that are to be made flush by mechanical means shall be shown by adding both the flush-contour symbol and the user's standard finish symbol* to the weld symbol, thus: (See also Fig. 28 (*B*).)



(*c*) Groove welds that are to be mechanically finished to a convex contour shall be shown by adding both the convex-contour symbol and the user's standard finish symbol* to the weld symbol, thus: (See also Fig. 28 (*C*).)

SECTION VI—DIMENSIONING OF PLUG WELDS

601. General

Dimensions of plug welds shall be shown on the same side of the reference line as the weld symbol, thus: (See also Fig. 30.)

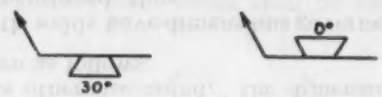
602. Size of Plug Welds

The size of a plug weld shall be shown to the left of the weld symbol, thus: (See also Fig. 30 (*A*).)

603. Angle of Countersink

(*a*) Included angle of countersink shall be the user's standard unless otherwise indicated.

(*b*) Included angle of countersink of plug welds, when not the user's standard, shall be shown thus: (See also Fig. 30(*B*).)



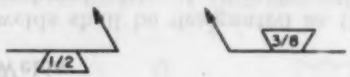
* Finish symbols used herein indicate the method of finishing ("*C*" = chipping; "*G*" = grinding; "*M*" = machining) and not the degree of finish.

"G" = grinding; "M" = machining) and not the degree of finish.

604. Depth of Filling

(*a*) Depth of filling of plug welds shall be complete unless otherwise indicated.

(*b*) When the depth of filling of plug welds is less than complete it shall be shown inside the weld symbol, thus: (See also Fig. 30 (*C*).)



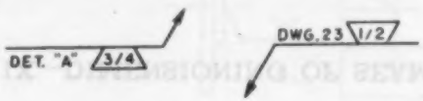
605. Spacing of Plug Welds

Pitch of plug welds shall be shown to the right of the weld symbol, thus: (See also Fig. 30 (*D*).)

SECTION VII—DIMENSIONING OF SLOT WELDS

701. General

Dimensions of slot welds shall be shown on the same side of the reference line as the weld symbol, thus: (See also Fig. 31.)



702. Details of Slot Welds

(*a*) Depth of filling of slot welds shall be complete unless otherwise indicated.

(*b*) When the depth of filling of slot welds is less than complete, it shall be shown inside the weld symbol, thus: (See also Fig. 31 (*B*).)

(*c*) Length, width, spacing, included angle of countersink, orientation and location of slot welds cannot be shown on the welding symbol. These data shall be shown by a detail with a reference thereto on the welding symbol, observing the usual location significance, thus: (See also Fig. 31.)

SECTION VIII—DIMENSIONING OF SPOT WELDS

801. General

(*a*) Spot welding symbols have no arrow- or other-side significance. Dimensions may be placed on either side of the reference line.

(*b*) Spot welds shall be dimensioned by either strength or size.

802. Strength of Spot Welds

Strength of spot welds shall be designated as the minimum acceptable shear strength in pounds per spot, and shall be shown to the left of the weld symbol, thus: (See also Fig. 32 (*B*).)

803. Size of Spot Welds

Size of spot welds shall be designated as the diameter of the weld expressed decimally in hundredths of an inch, and shall be shown with inch marks to the left of the weld symbol, thus: (See also Fig. 32 (*A*).)

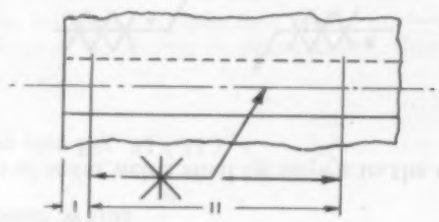
804. Spacing of Spot Welds

(*a*) Pitch of spot welds shall be shown to the right of the weld symbol, thus: (See also Fig. 32 (*C*).)

(*b*) When spot weld symbols are shown directly on the drawing, spacing shall be shown by dimensions. (See Fig. 32 (*D*).)

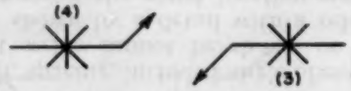
805. Extent of Spot Welding

When spot welding extends less than the distance between abrupt changes in the direction of the joint, the extent shall be dimensioned, thus: (See also Fig. 33 (*A*).)



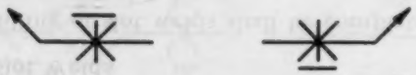
806. Number of Spot Welds

When a definite number of spot welds is desired in a certain joint, the number shall be shown in parentheses either above or below the weld symbol, thus: (See also Fig. 33 (*B*).)



807. Flush Spot Welded Joints

When the exposed surface of one member of a spot welded joint is to be flush, that surface shall be indicated by adding the flush-contour symbol to the weld symbol, observing the usual location significance, thus:



SECTION IX—DIMENSIONING OF SEAM WELDS

901. General

(*a*) Seam welding symbols have no arrow- or other-side significance. Dimensions may be placed on either side of the reference line.

(*b*) Seam welds shall be dimensioned by either strength or size.

902. Strength of Seam Welds

The strength of seam welds shall be designated as the minimum acceptable shear strength in pounds per linear inch, and shall be shown to the left of the weld symbol, thus: (See also Fig. 34 (*B*).)

903. Size of Seam Welds

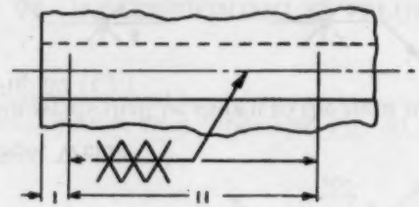
The size of seam welds shall be designated as the width of the weld expressed decimally in hundredths of an inch, and shall be shown with inch marks to the left of the weld symbol, thus:

904. Length of Seam Welds

(*a*) The length of seam welds shall be shown to the right of the weld symbol, thus: (See also Fig. 34 (*A*).)

(*b*) When a seam weld extends for the full length of the joint, no length dimension need be shown on the welding symbol.

(*c*) When seam welding extends less than the distance between abrupt changes in the direction of the joint, the extent shall be dimensioned, thus: (See also Fig. 34 (*C*).)



905. Spacing of Intermittent Seam Welds

Pitch of intermittent seam welds shall be shown to the right of the length dimension, thus: (See also Fig. 34 (*A*).)

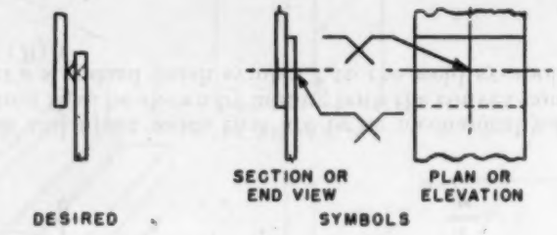
906. Flush Seam Welded Joints

When the exposed surface of one member of a seam welded joint is to be flush, that surface shall be indicated by adding the flush-contour symbol to the weld symbol, observing the usual location significance, thus:

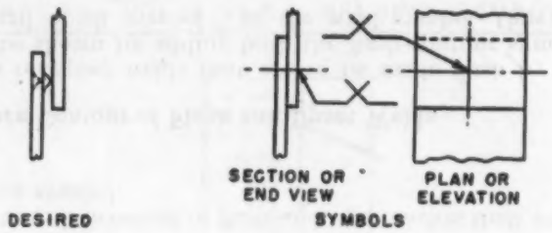
SECTION X—DIMENSIONING OF PROJECTION WELDS

1001. General

(*a*) Embossments on the arrow-side member of a joint for projection welding shall be indicated by placing the weld symbol on the side of the reference line toward the reader, thus: (See also Fig. 16 (*A*).)



(*b*) Embossments on the other-side member of a joint for projection welding shall be indicated by placing the weld symbol on the side of the reference line away from the reader, thus: (See also Fig. 16 (*B*).)



(*c*) Proportions of projections shall be shown by a detail or other suitable means.

(*d*) Dimensions of projection welds shall be shown on the same side of the reference line as the weld symbol, thus: (See also Fig. 36 (*C*).)

(*e*) Projection welds shall be dimensioned by either strength or size.

1002. Strength of Projection Welds

Strength of projection welds shall be designated as the minimum acceptable shear strength in pounds per weld, and shall be shown to the left of the weld symbol, thus: (See also Fig. 35 (*B*).)

1003. Size of Projection Welds

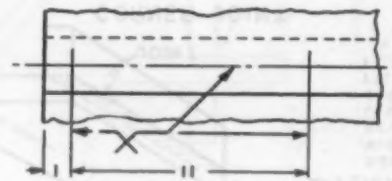
Size of projection welds shall be designated as the diameter of the weld expressed decimally in hundredths of an inch, and shall be shown, with inch marks, to the left of the weld symbol, thus: (See also Fig. 35 (*A*).)

1004. Spacing of Projection Welds

Pitch of projection welds shall be shown to the right of the weld symbol, thus: (See also Fig. 35 (*C*).)

1005. Extent of Projection Welding

When projection welding extends less than the distance between abrupt changes in the direction of the joint, the extent shall be dimensioned, thus: (See also Fig. 36 (*A*).)



1006. Number of Projection Welds

When a definite number of projection welds is desired in a certain joint, the number shall be shown in parentheses, thus: (See also Fig. 36 (*B*).)

1007. Flush Projection Welded Joints

When the indented surface of a projection welded joint is to be made flush, that surface shall be indicated by adding the flush-contour symbol to the weld symbol, thus:

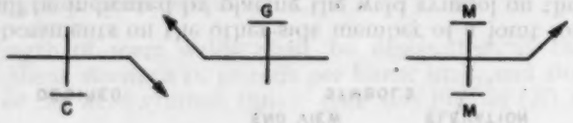
SECTION XI—DIMENSIONING OF FLASH AND UPSET WELDS

1101. General

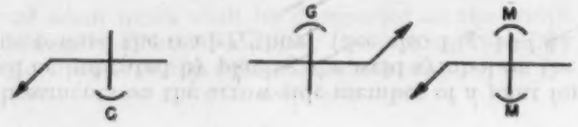
Size and other dimensions of flash and upset welds shall not be shown on the welding symbol.

1102. Surface Contour of Flash and Upset Welds

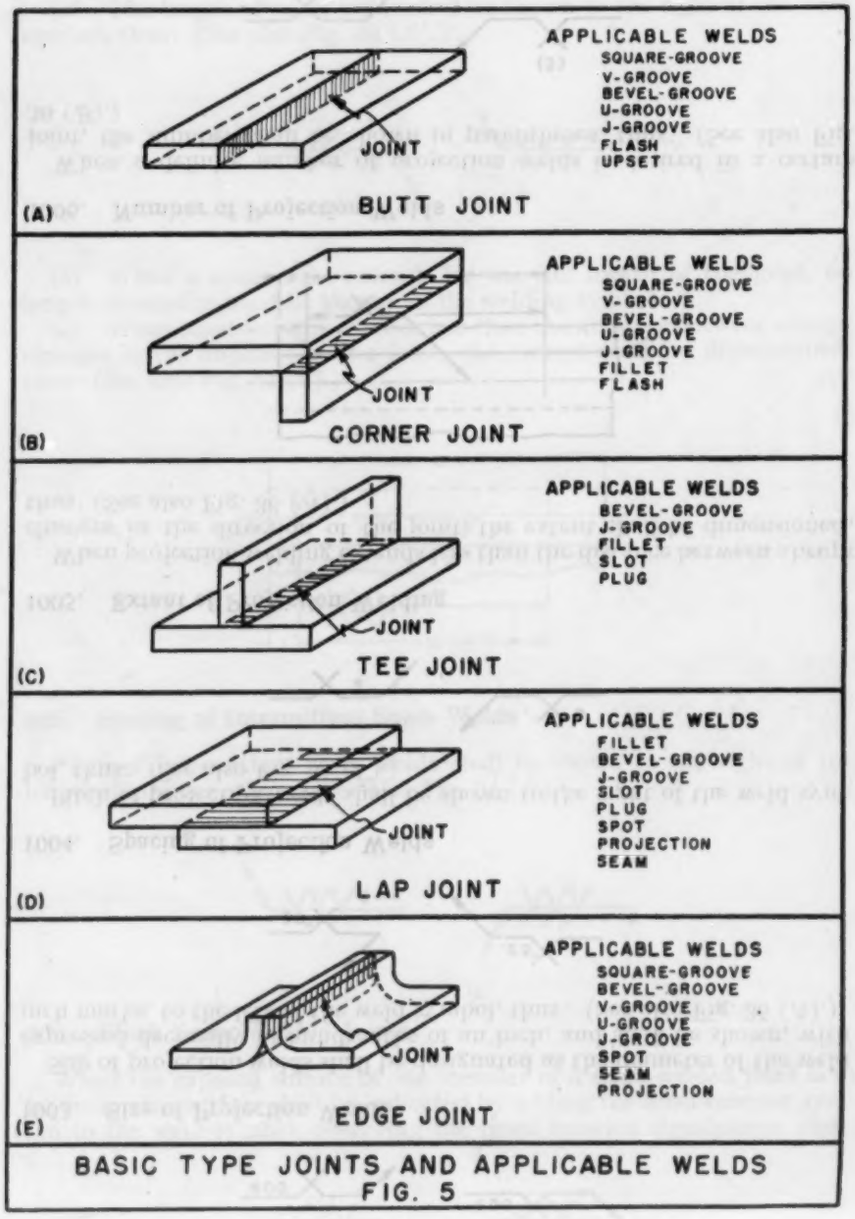
(*a*) Flash or upset welds that are to be made flush by mechanical means shall be shown by adding both the flush-contour symbol and the user's standard finish symbol * to the weld symbol, thus: (See also Fig. 37 (*A*).)



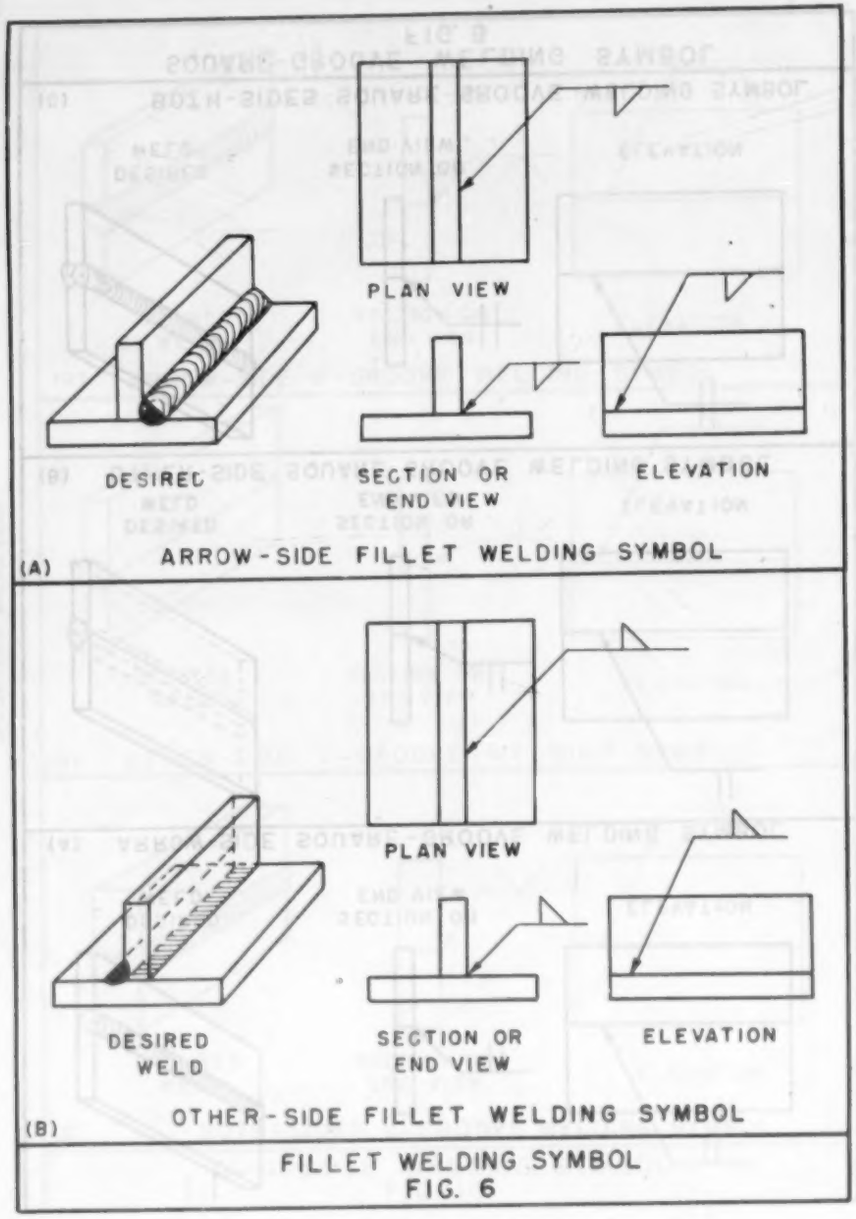
(*b*) Flash and upset welds that are to be mechanically finished to a convex contour shall be shown by adding both the convex-contour symbol and the user's standard finish symbol * to the weld symbol, thus: (See also Fig. 37 (*B*).)



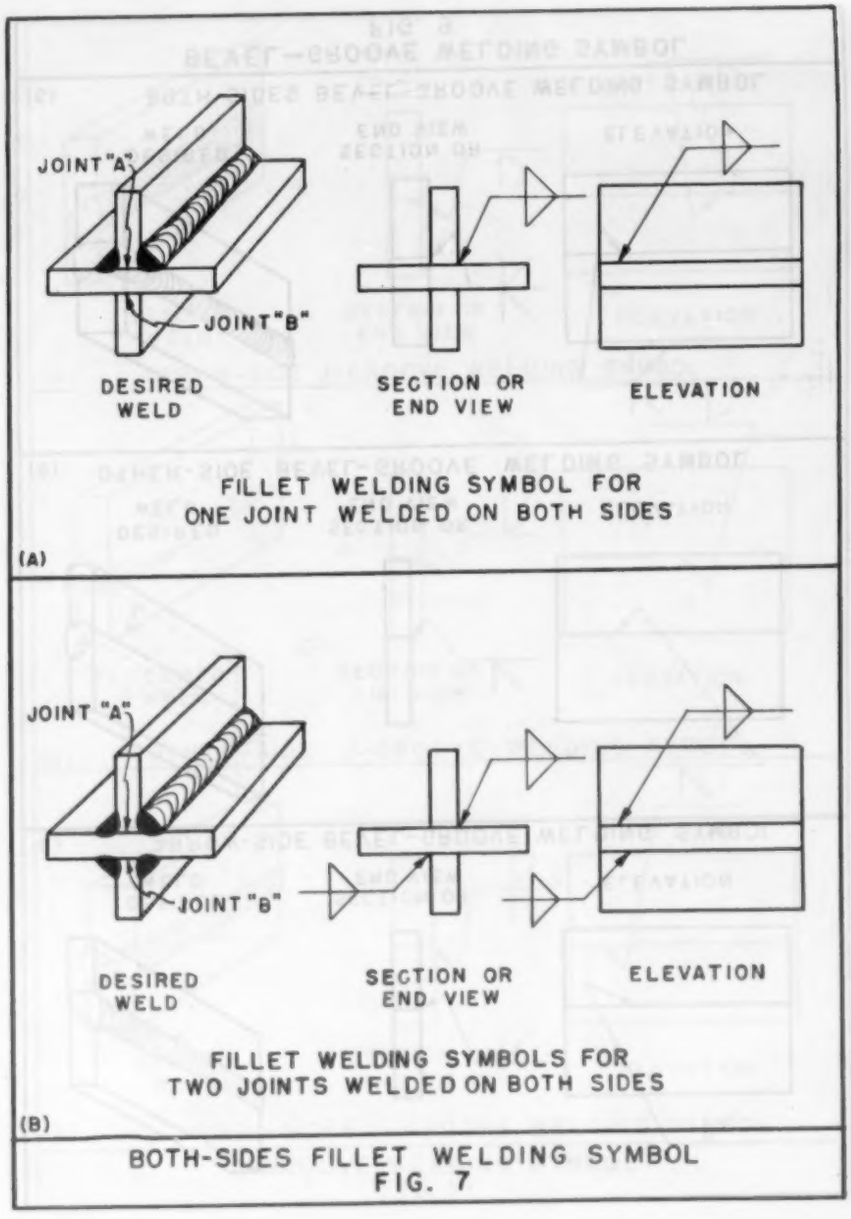
* Finished symbols used herein indicated the method of finishing ("*C*" = chipping; "*G*" = grinding; "*M*" = machining) and not the degree of finish.



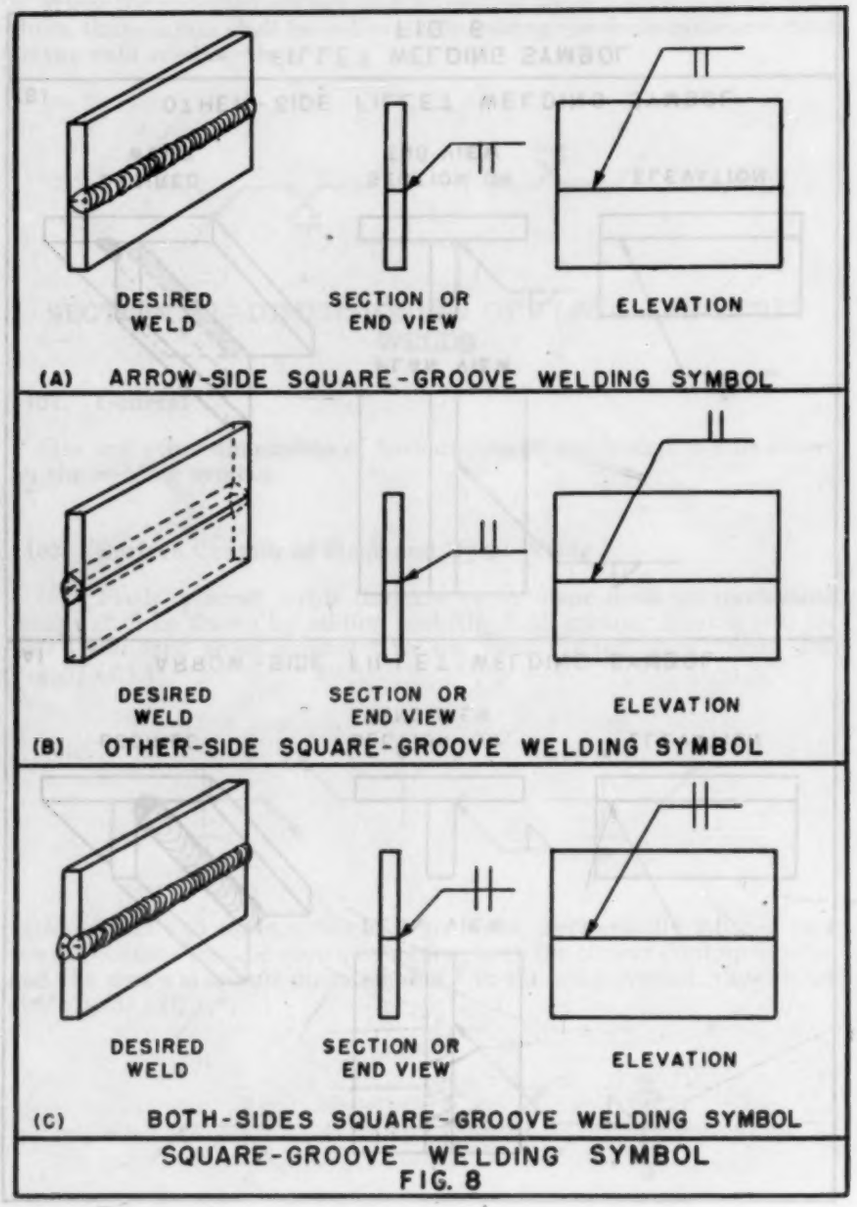
BASIC TYPE JOINTS AND APPLICABLE WELDS
FIG. 5



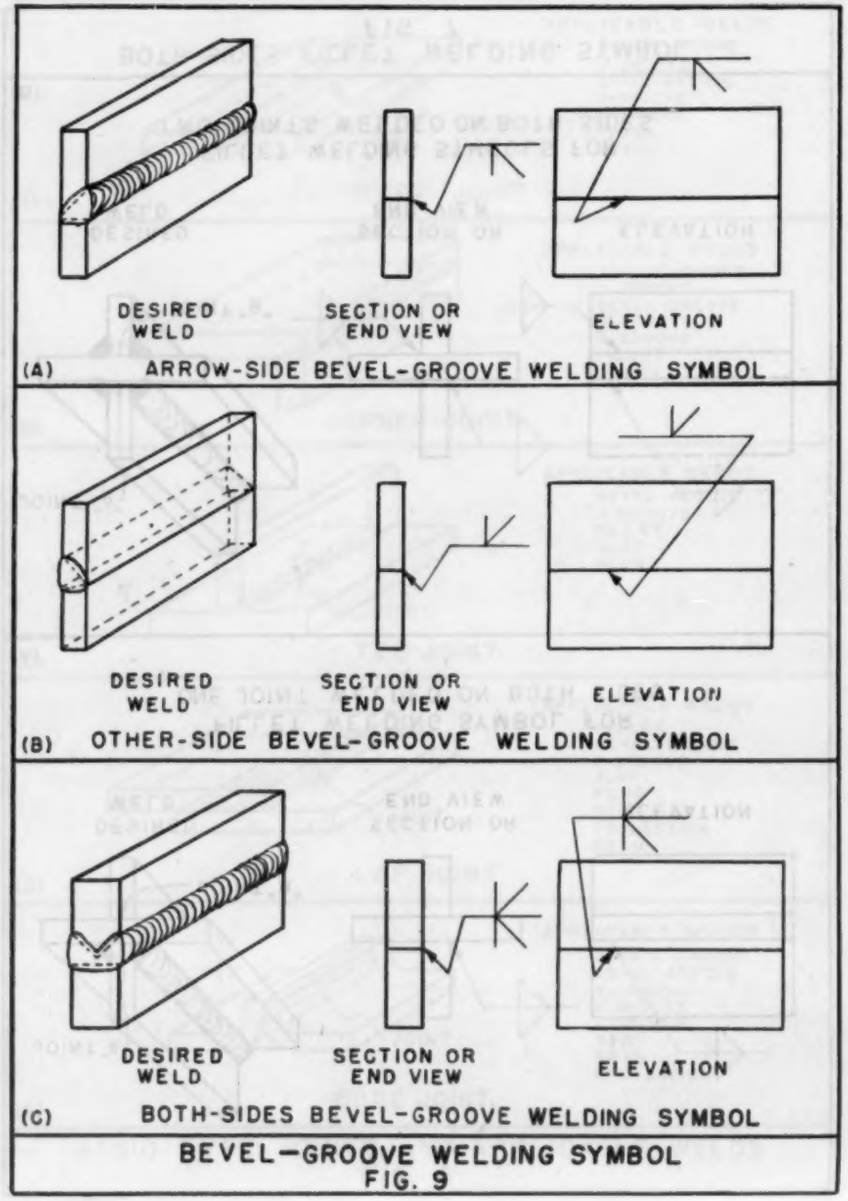
FILLET WELDING SYMBOL
FIG. 6



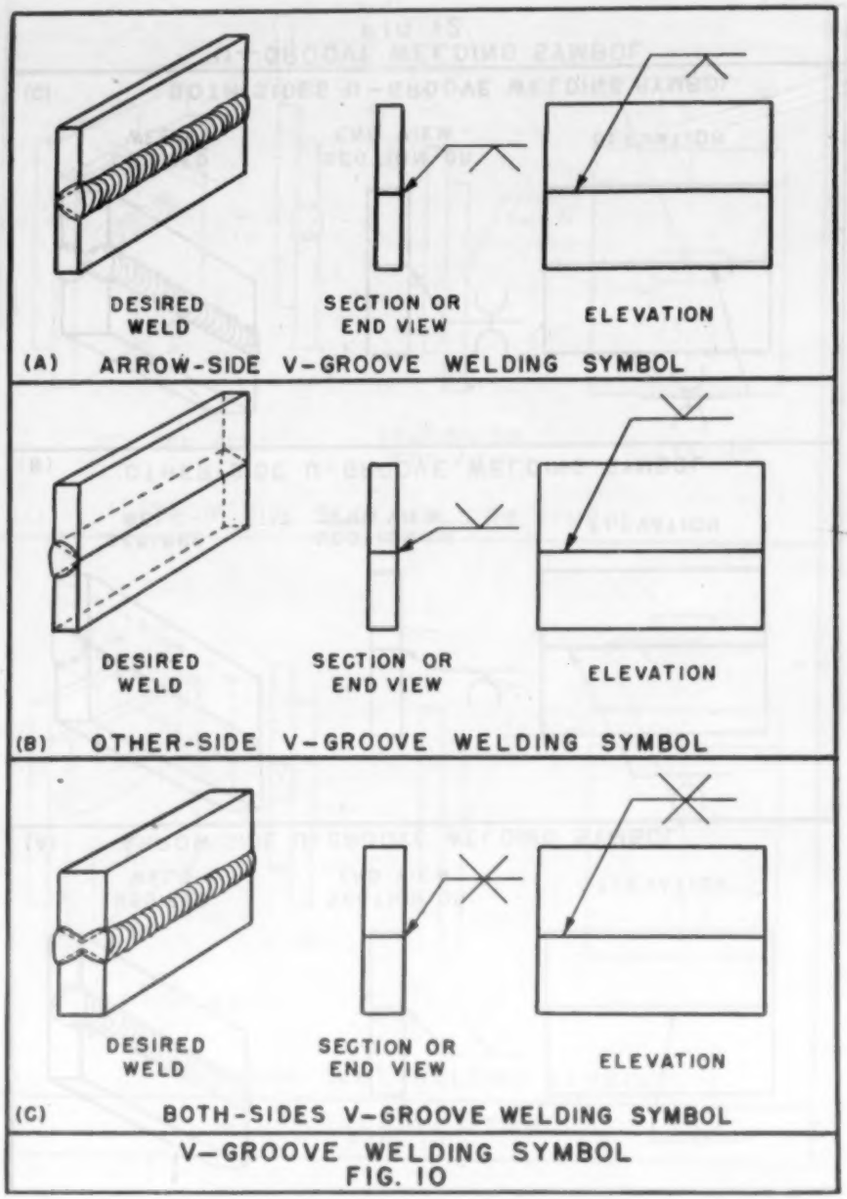
BOTH-SIDES FILLET WELDING SYMBOL
FIG. 7



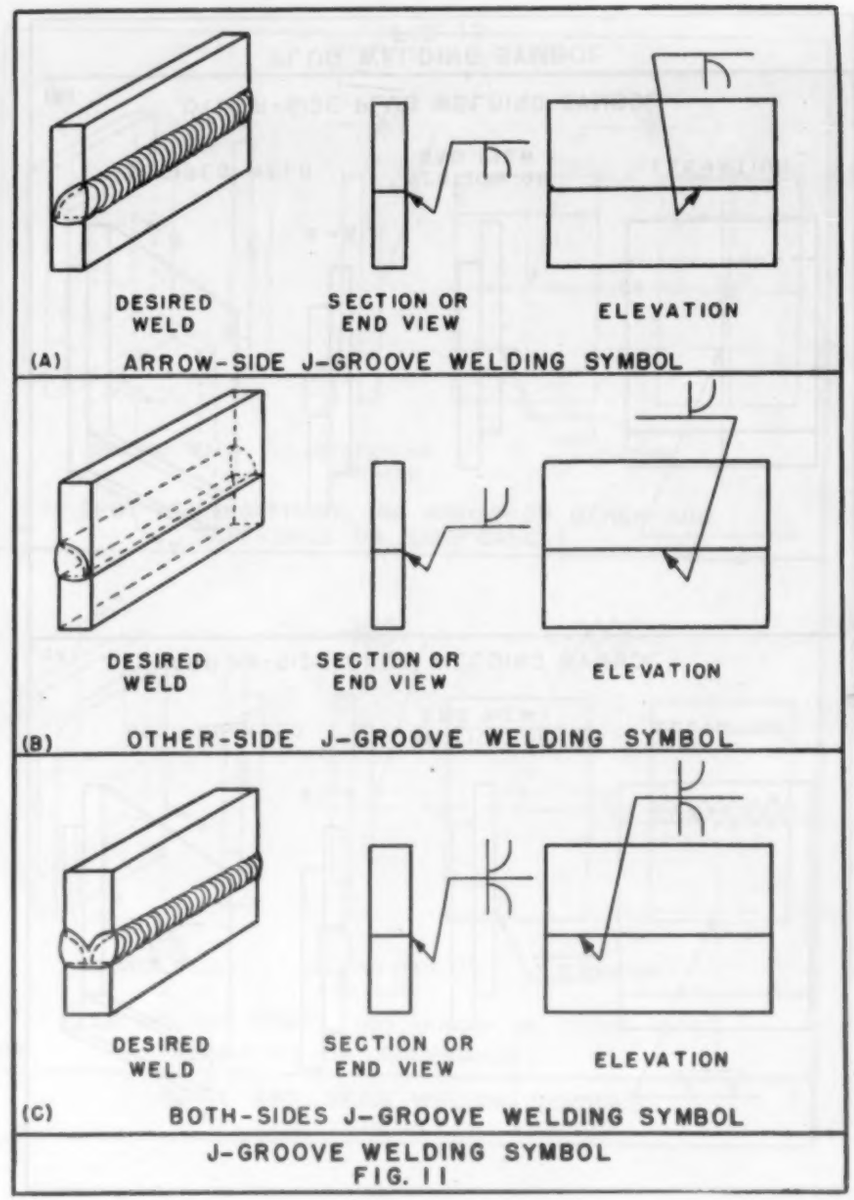
SQUARE-GROOVE WELDING SYMBOL
FIG. 8



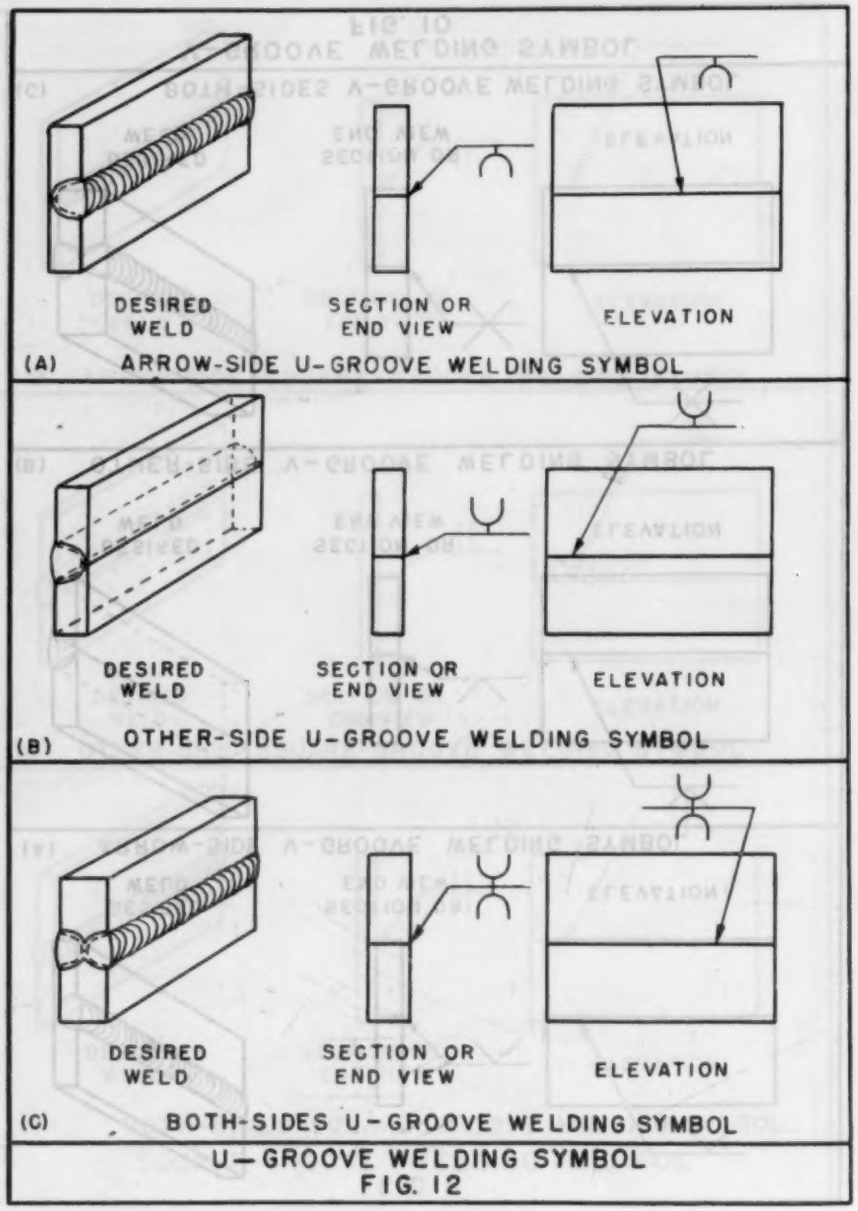
BEVEL-GROOVE WELDING SYMBOL
FIG. 9



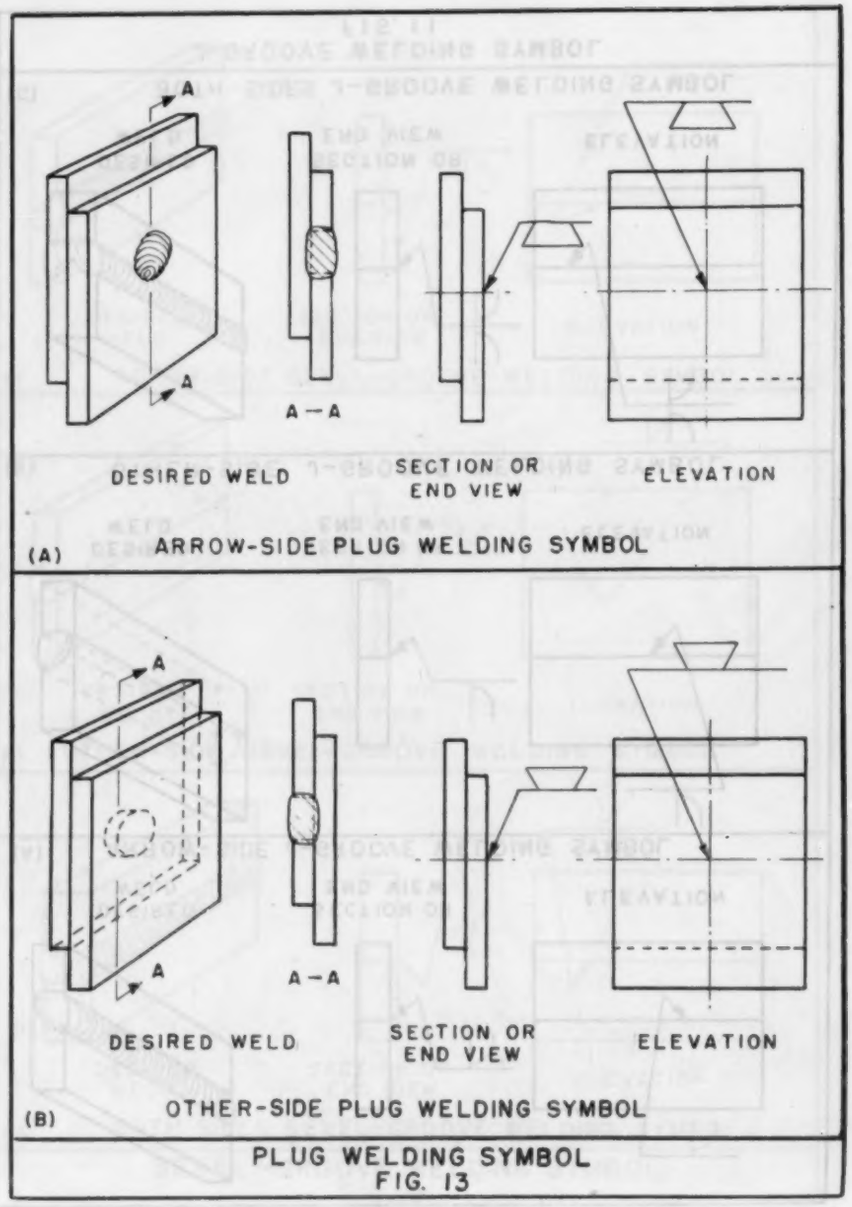
V-GROOVE WELDING SYMBOL
FIG. 10



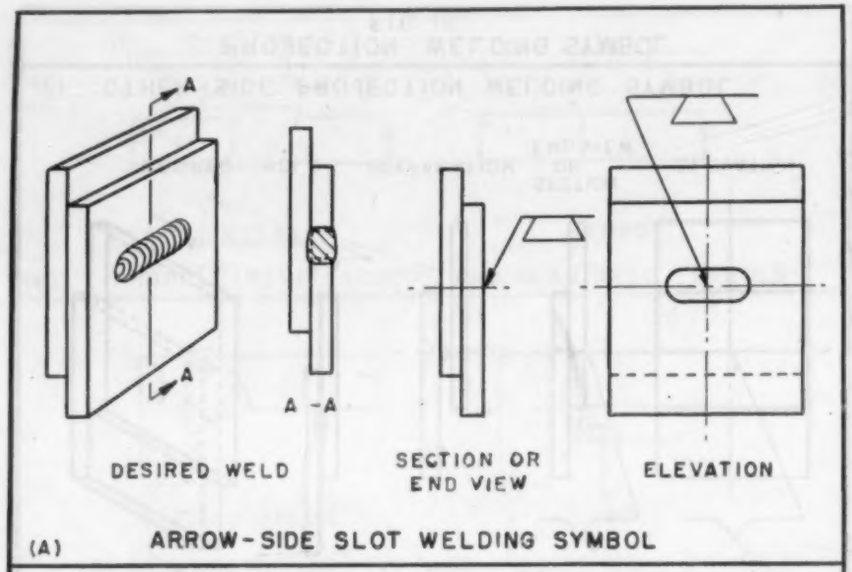
J-GROOVE WELDING SYMBOL
FIG. 11



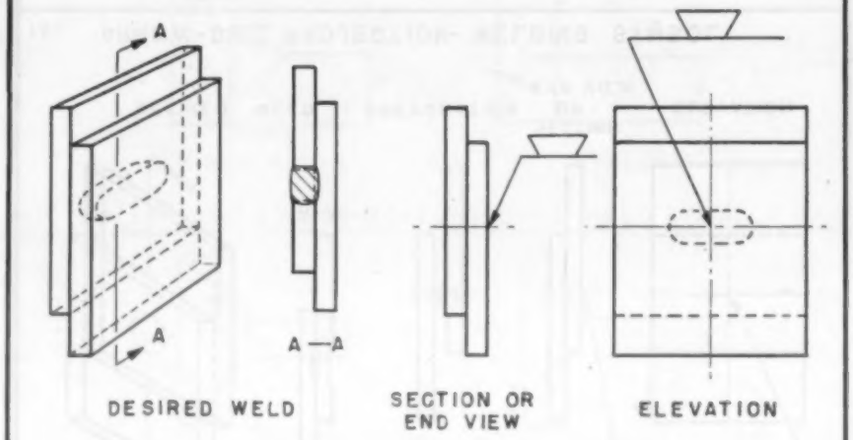
U—GROOVE WELDING SYMBOL
FIG. 12



PLUG WELDING SYMBOL
FIG. 13

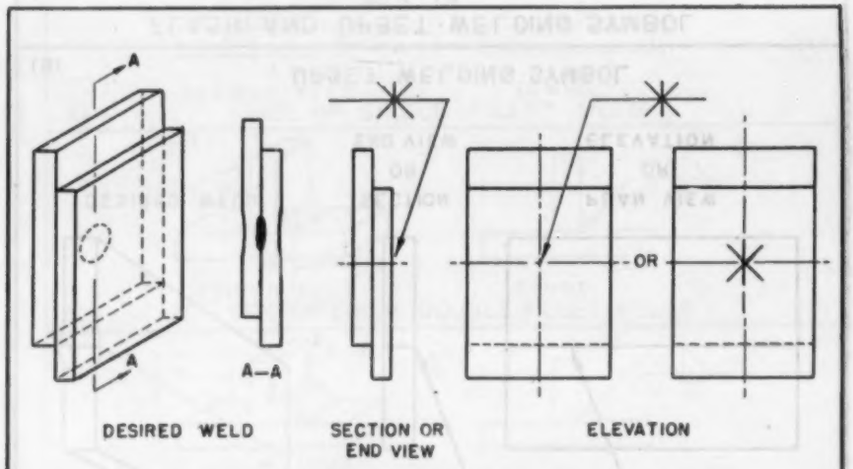


(A) ARROW-SIDE SLOT WELDING SYMBOL

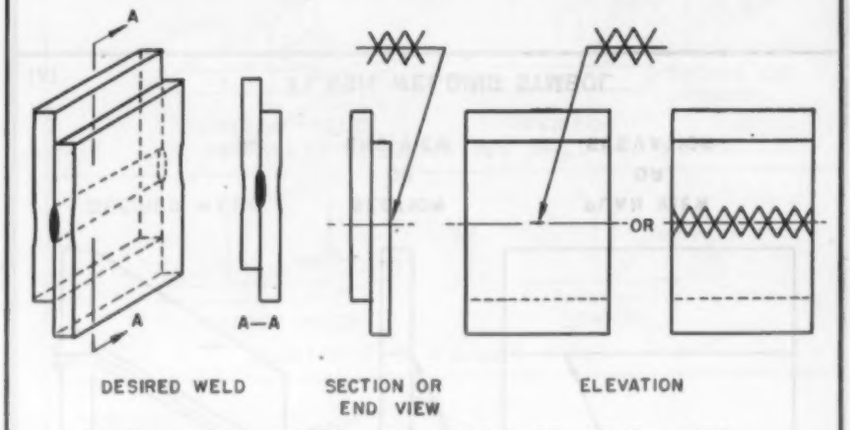


(B) OTHER-SIDE SLOT WELDING SYMBOL

SLOT WELDING SYMBOL
FIG. 14

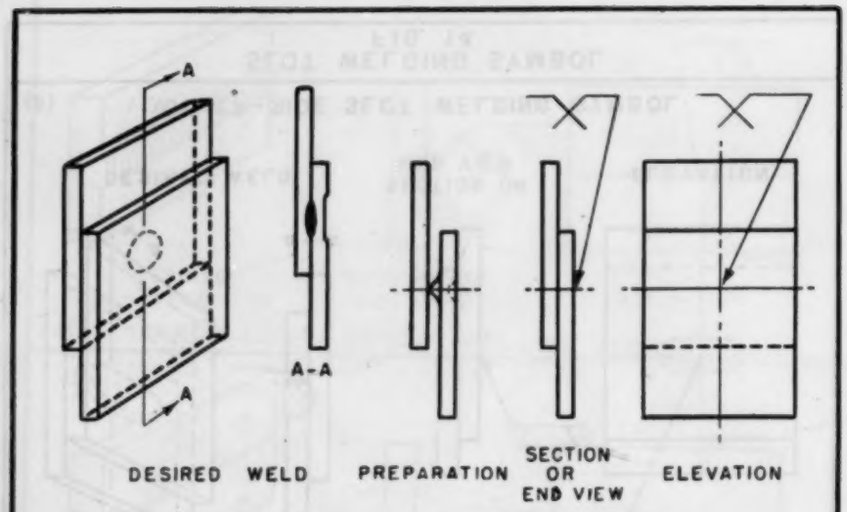


(A) SPOT WELDING SYMBOL (NO ARROW- OR OTHER-SIDE REFERENCE OR SIGNIFICANCE)

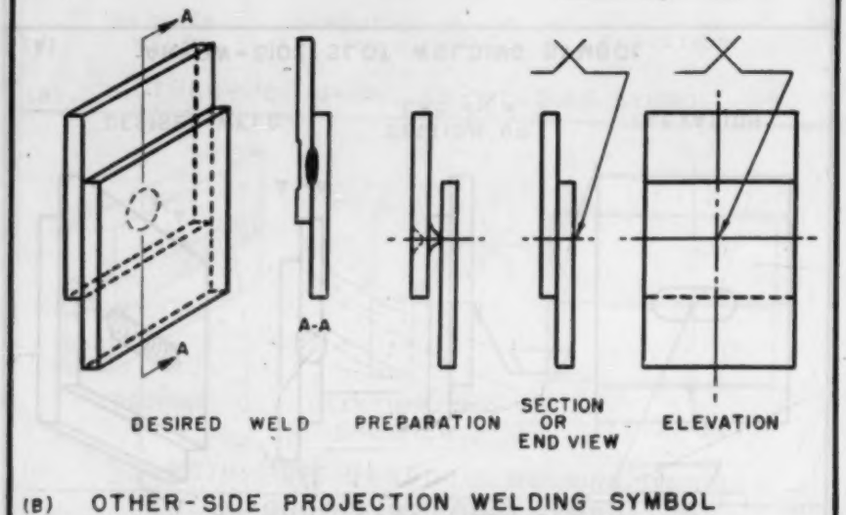


(B) SEAM WELDING SYMBOL (NO ARROW- OR OTHER-SIDE REFERENCE OR SIGNIFICANCE.)

SPOT AND SEAM WELDING SYMBOLS
FIG. 15

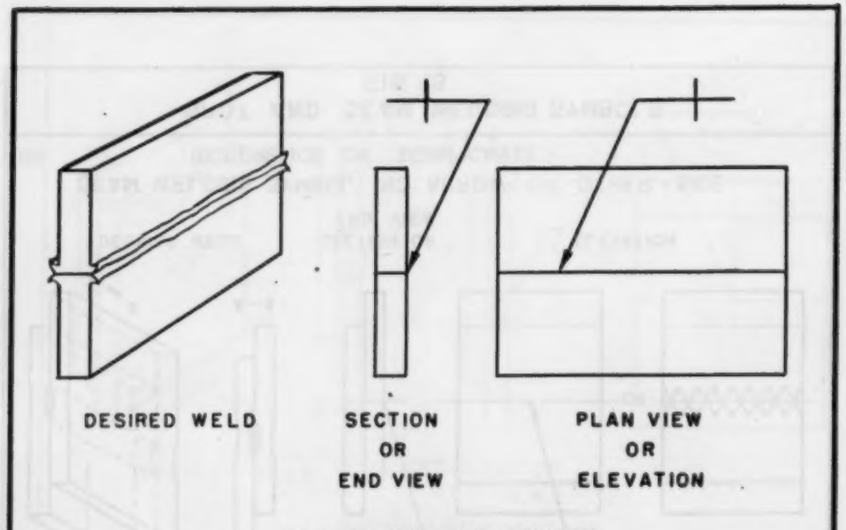


(A) ARROW-SIDE PROJECTION WELDING SYMBOL

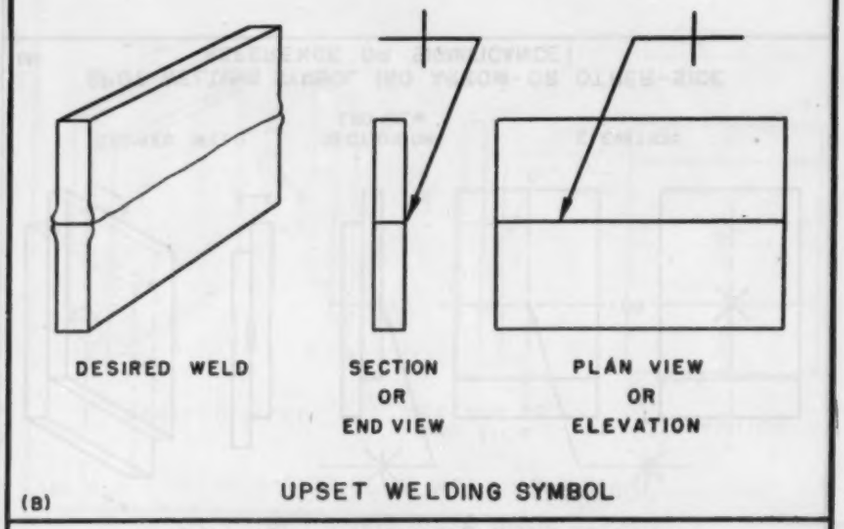


(B) OTHER-SIDE PROJECTION WELDING SYMBOL

PROJECTION WELDING SYMBOL
FIG. 16

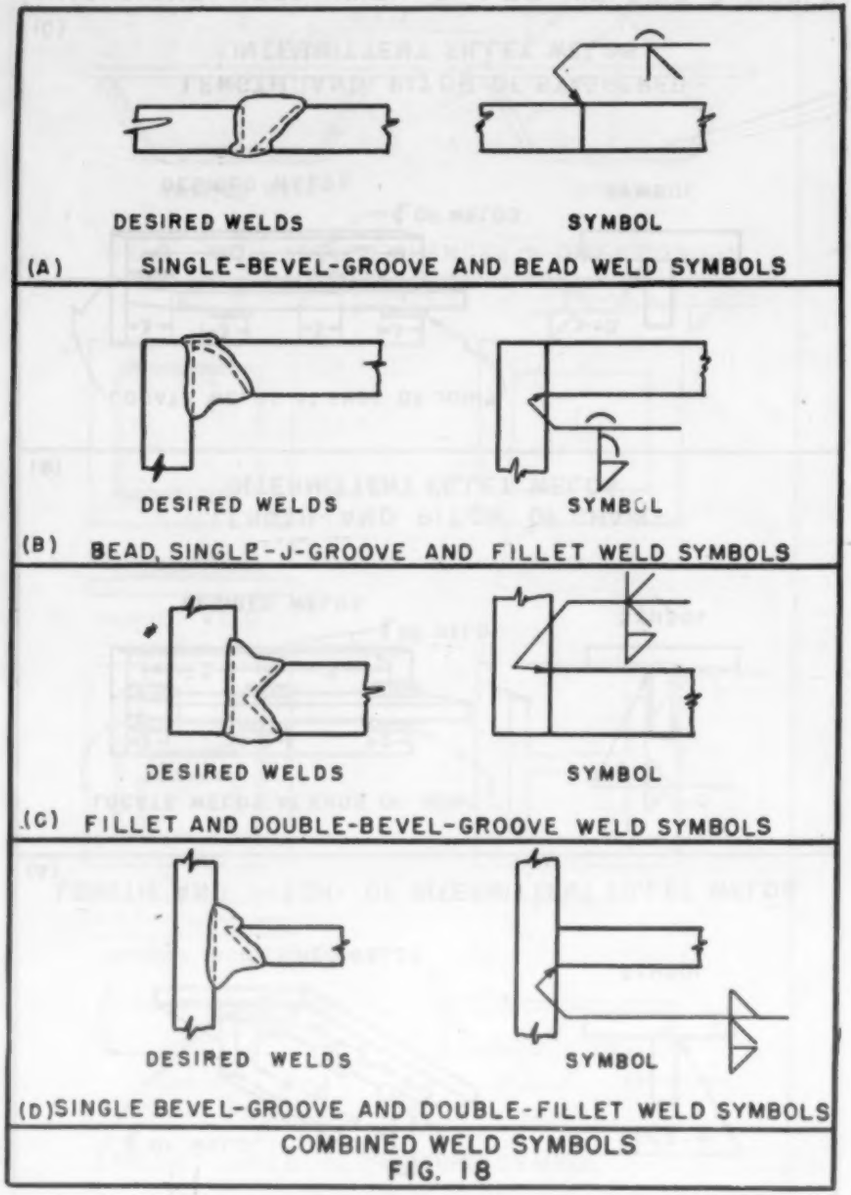


(A) FLASH WELDING SYMBOL

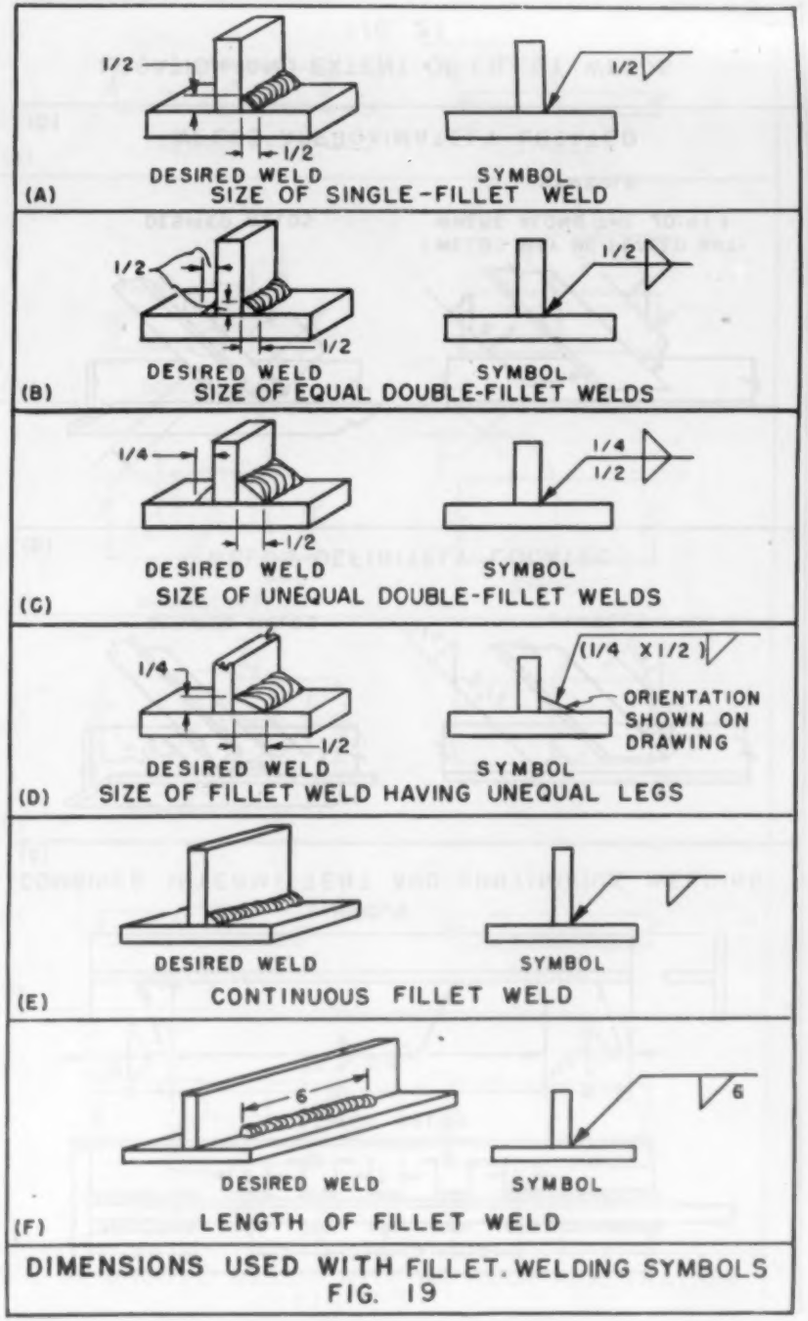


(B) UPSET WELDING SYMBOL

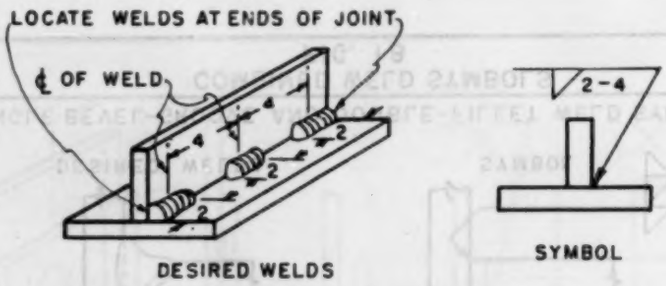
FLASH AND UPSET WELDING SYMBOL
FIG. 17



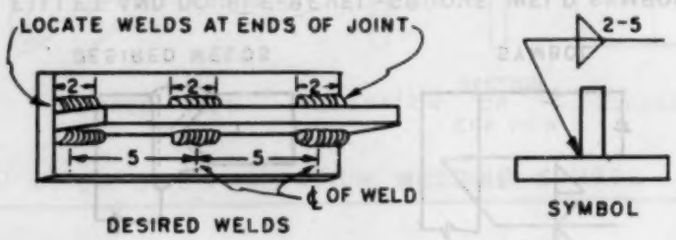
COMBINED WELD SYMBOLS
FIG. 18



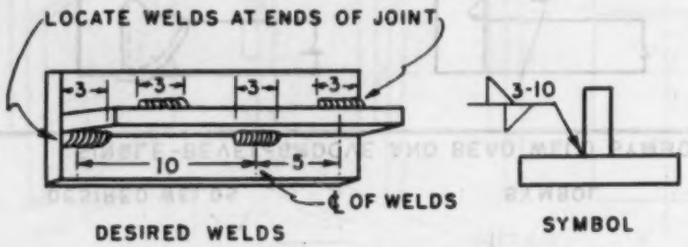
DIMENSIONS USED WITH FILLET WELDING SYMBOLS
FIG. 19



(A) LENGTH AND PITCH OF INTERMITTENT FILLET WELDS

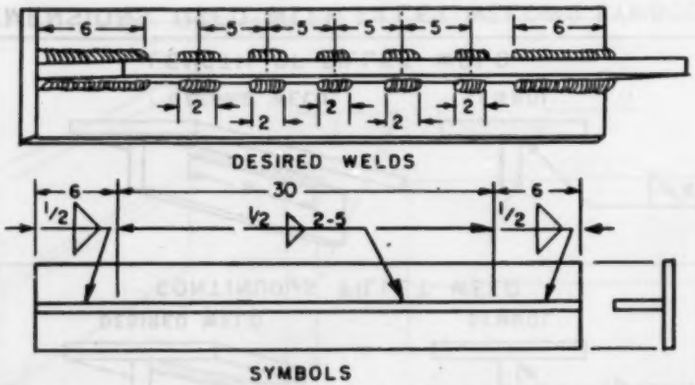


(B) LENGTH AND PITCH OF CHAIN-INTERMITTENT FILLET WELDS

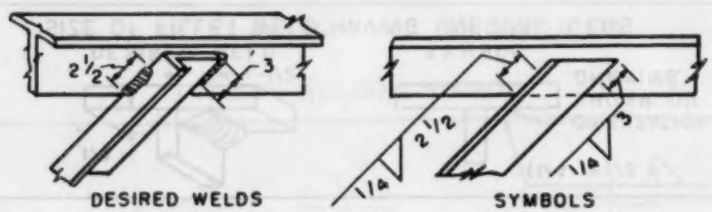


(C) LENGTH AND PITCH OF STAGGERED-INTERMITTENT FILLET WELDS

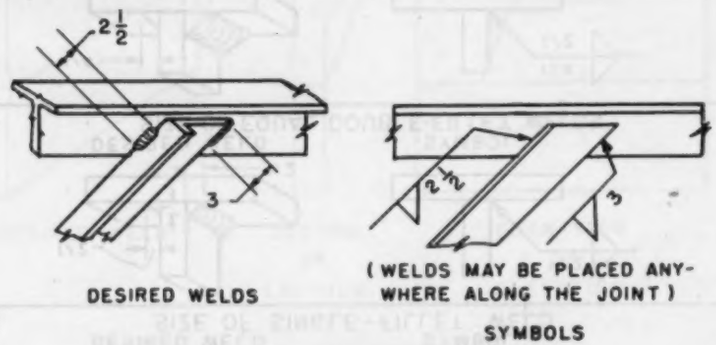
DIMENSIONS USED WITH FILLET WELDING SYMBOLS
FIG. 20



(A) COMBINED INTERMITTENT AND CONTINUOUS WELDING

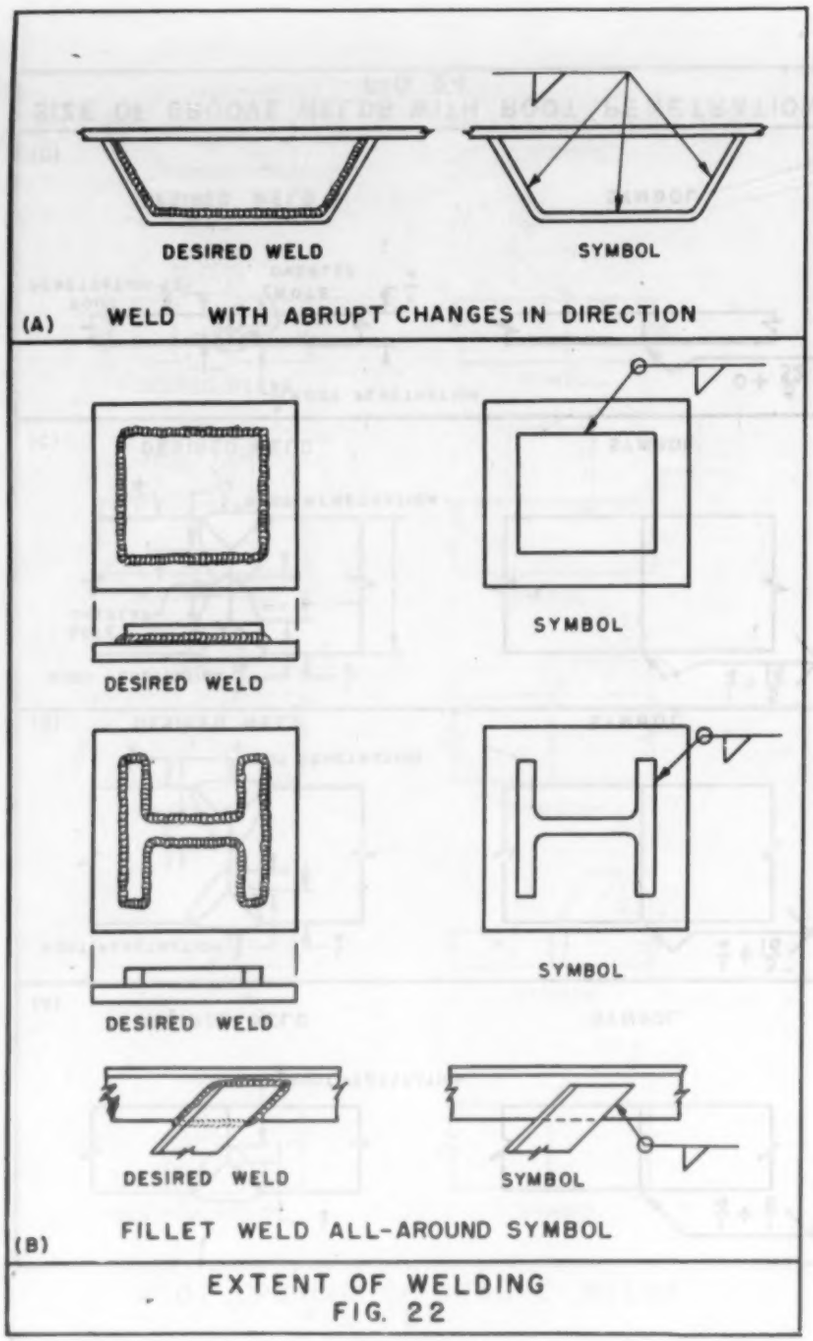


(B) WELDS DEFINITELY LOCATED

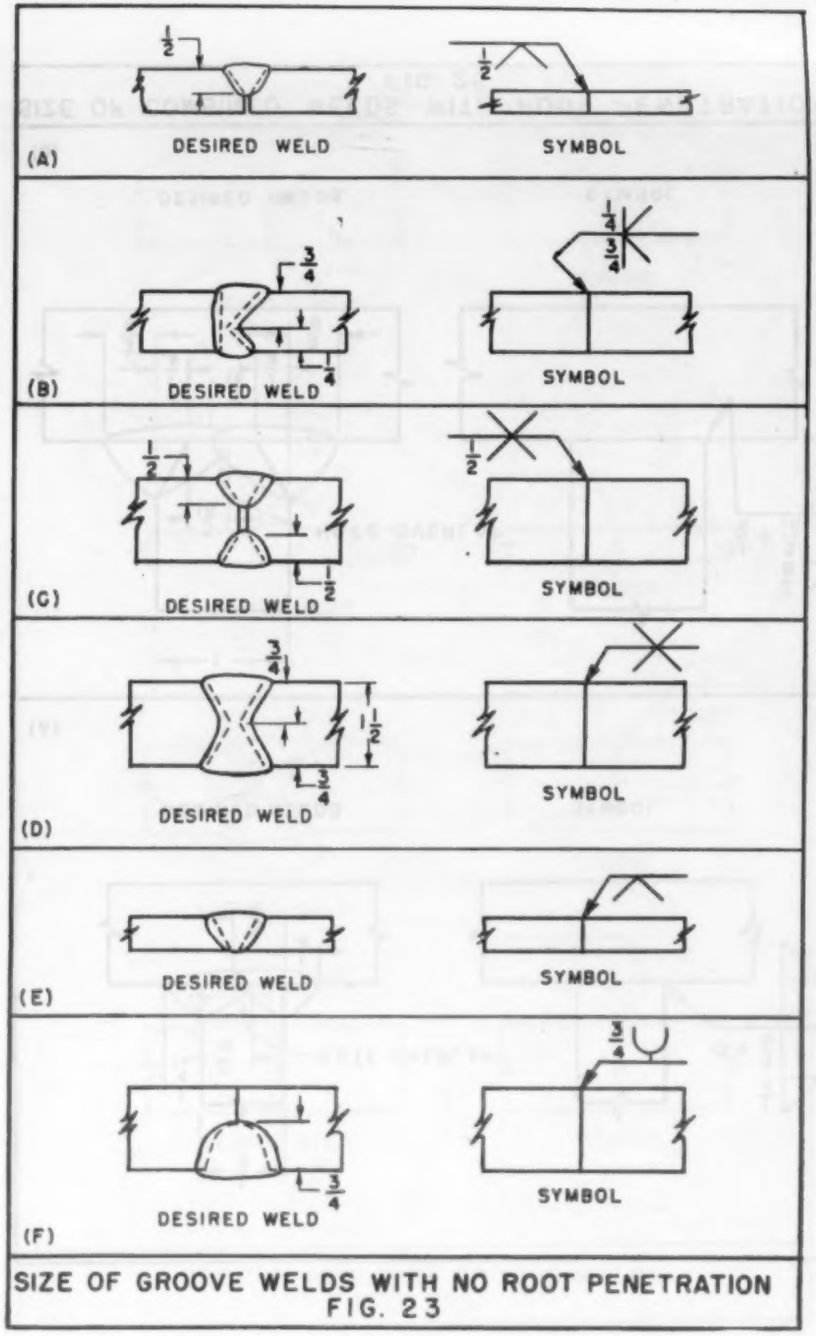


(C) WELDS APPROXIMATELY LOCATED

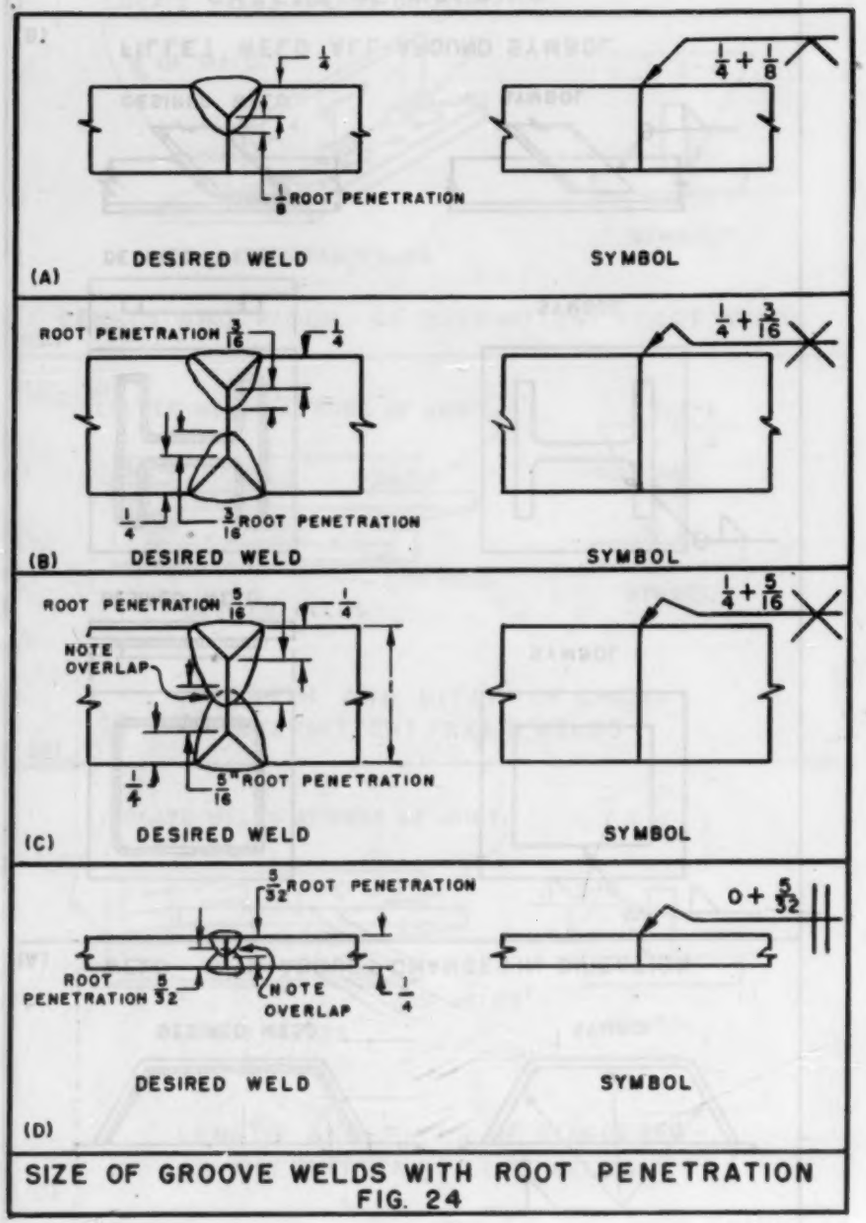
LOCATION AND EXTENT OF FILLET WELDS
FIG. 21



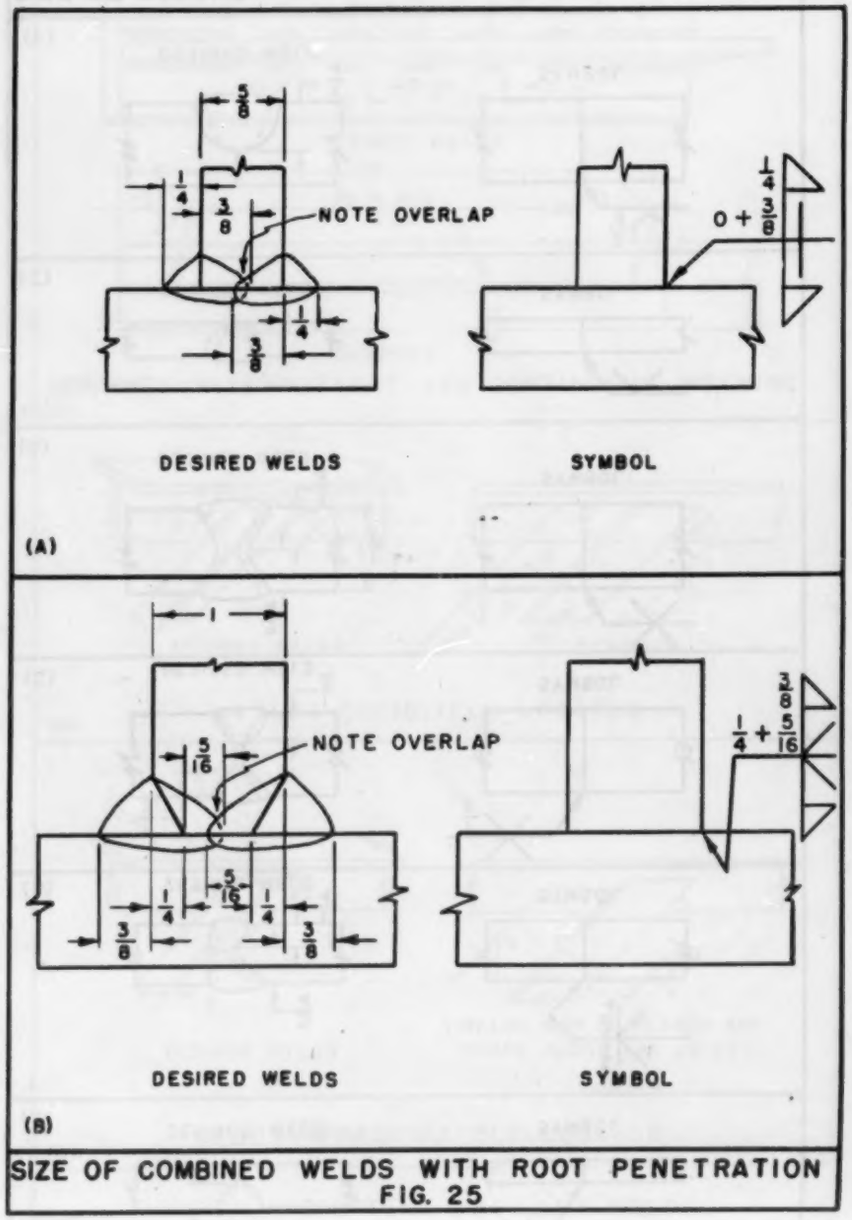
EXTENT OF WELDING
FIG. 22



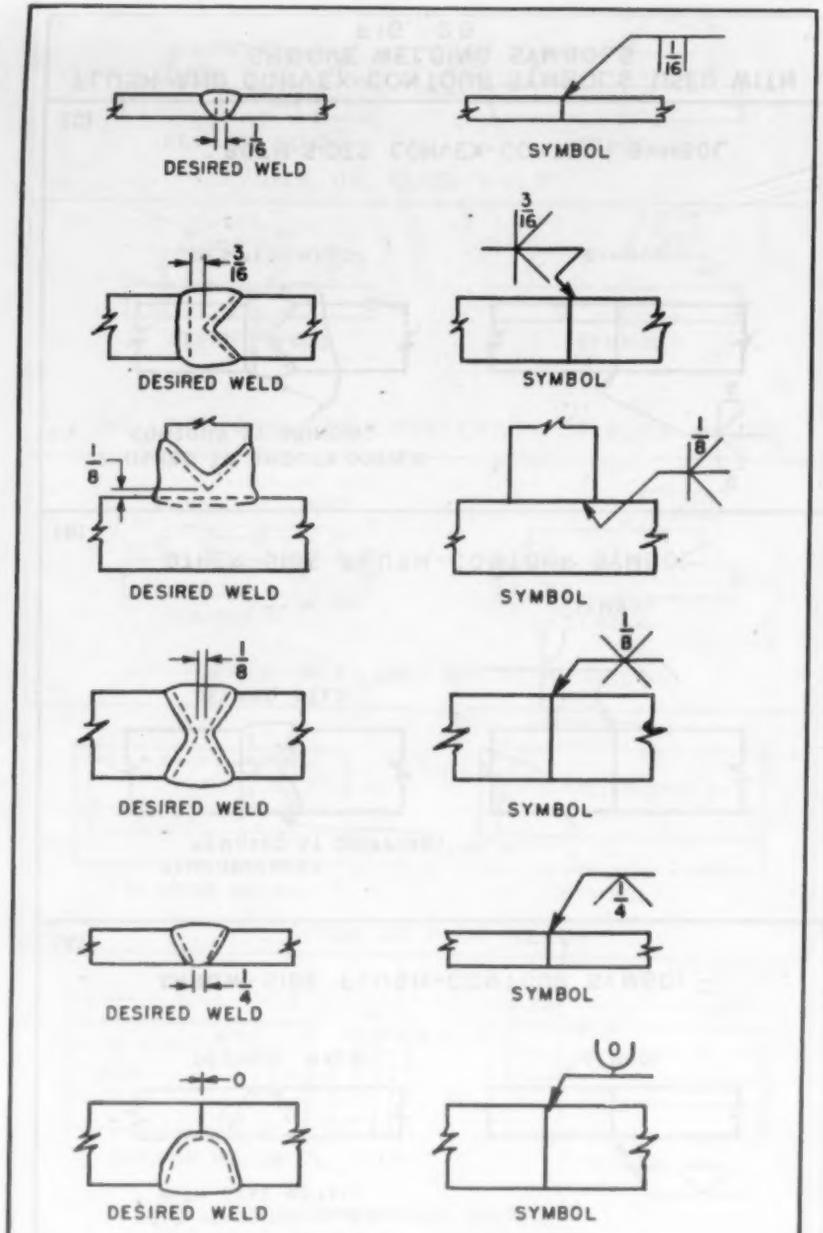
SIZE OF GROOVE WELDS WITH NO ROOT PENETRATION
FIG. 23



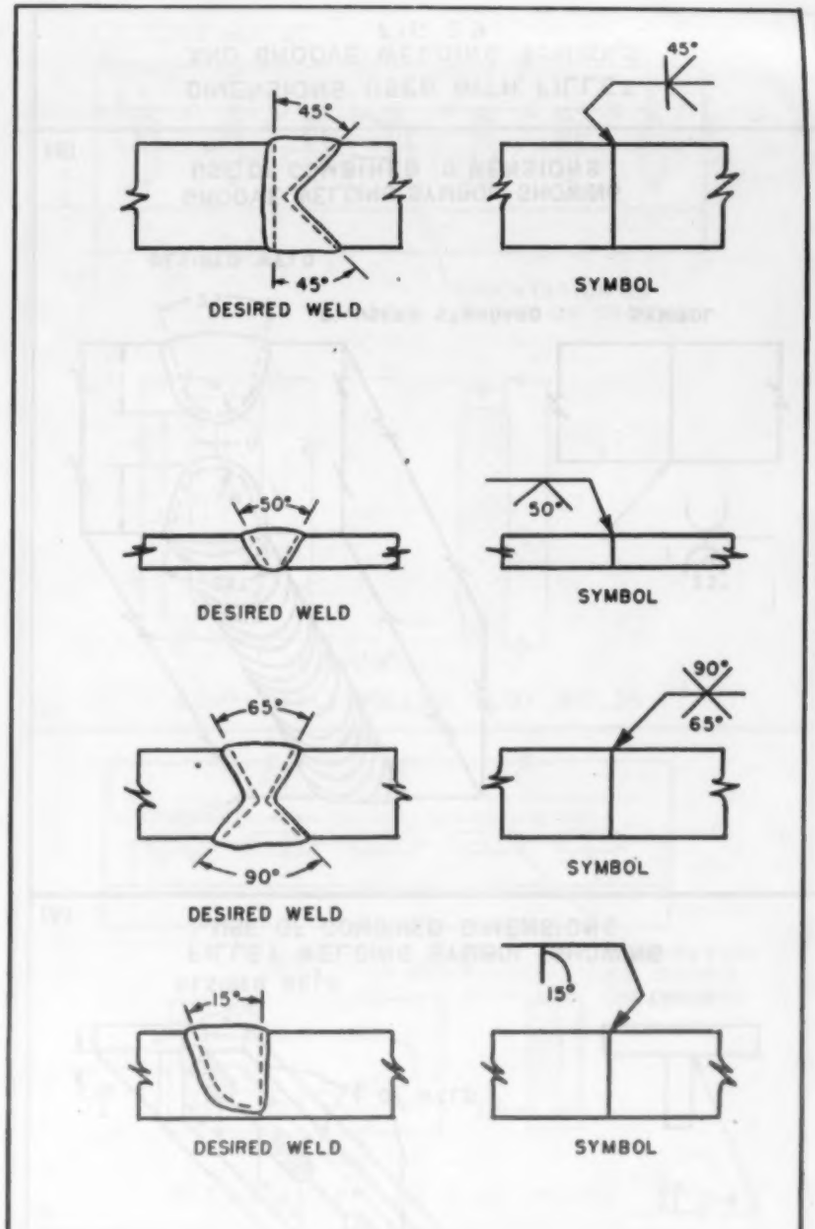
SIZE OF GROOVE WELDS WITH ROOT PENETRATION
FIG. 24



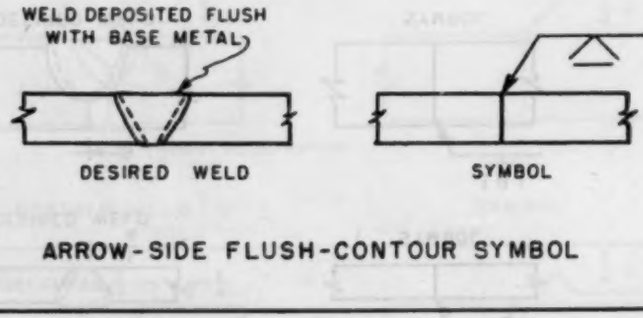
SIZE OF COMBINED WELDS WITH ROOT PENETRATION
FIG. 25



ROOT OPENING OF GROOVE WELDS
FIG. 26

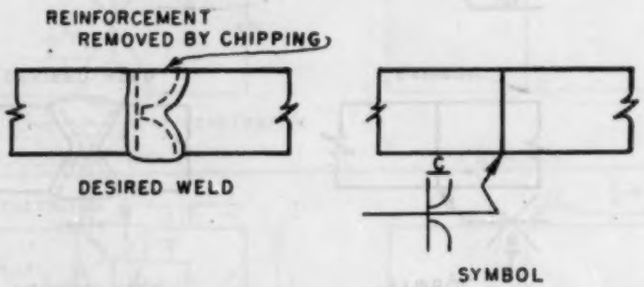


GROOVE ANGLE OF GROOVE WELDS
FIG. 27



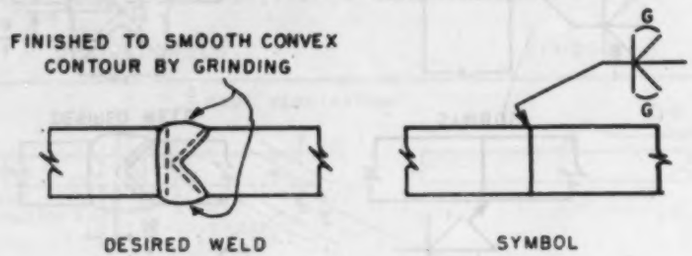
ARROW-SIDE FLUSH-CONTOUR SYMBOL

(A)



OTHER-SIDE FLUSH-CONTOUR SYMBOL

(B)

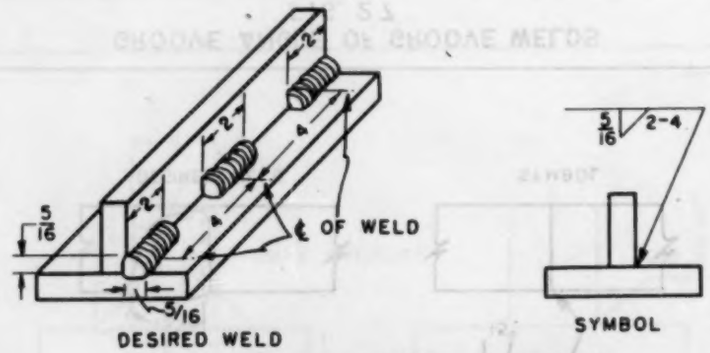


BOTH-SIDES CONVEX-CONTOUR SYMBOL

(C)

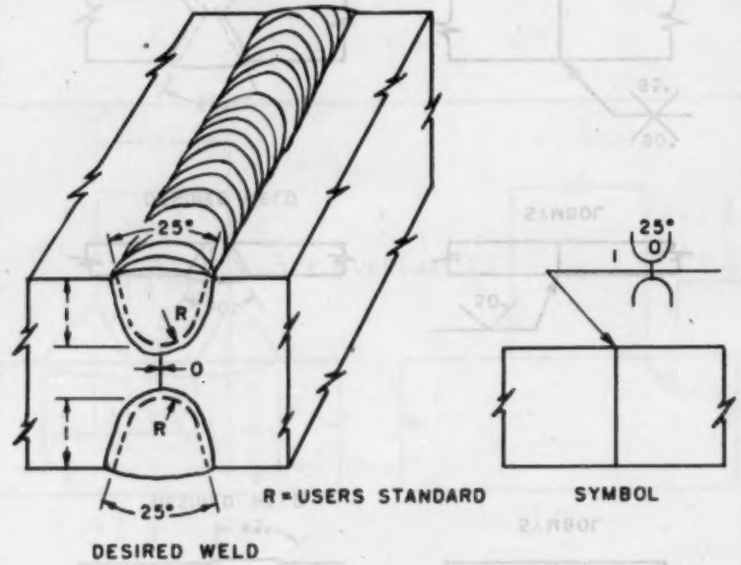
FLUSH-AND CONVEX-CONTOUR SYMBOLS USED WITH GROOVE WELDING SYMBOLS

FIG. 28



FILLET WELDING SYMBOL SHOWING USE OF COMBINED DIMENSIONS

(A)

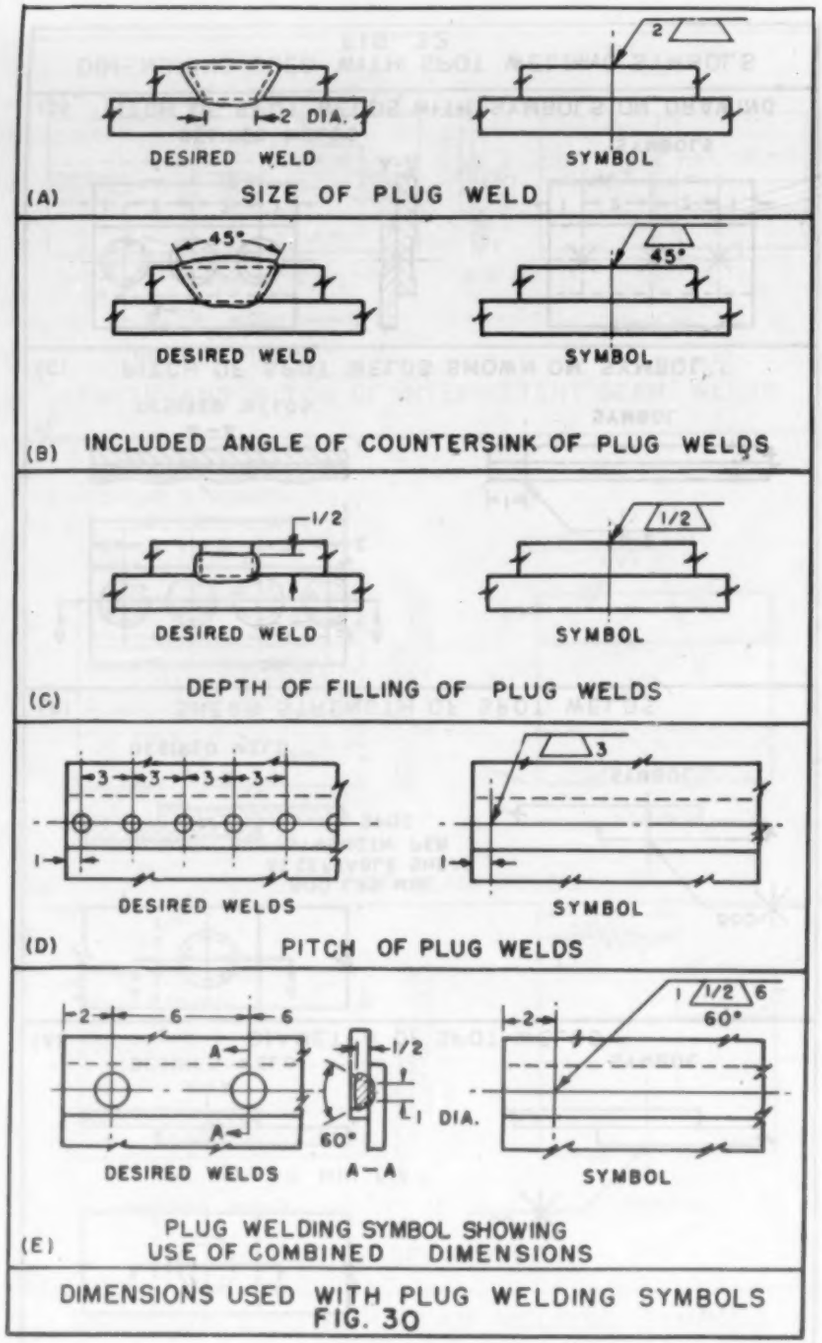


GROOVE WELDING SYMBOL SHOWING USE OF COMBINED DIMENSIONS

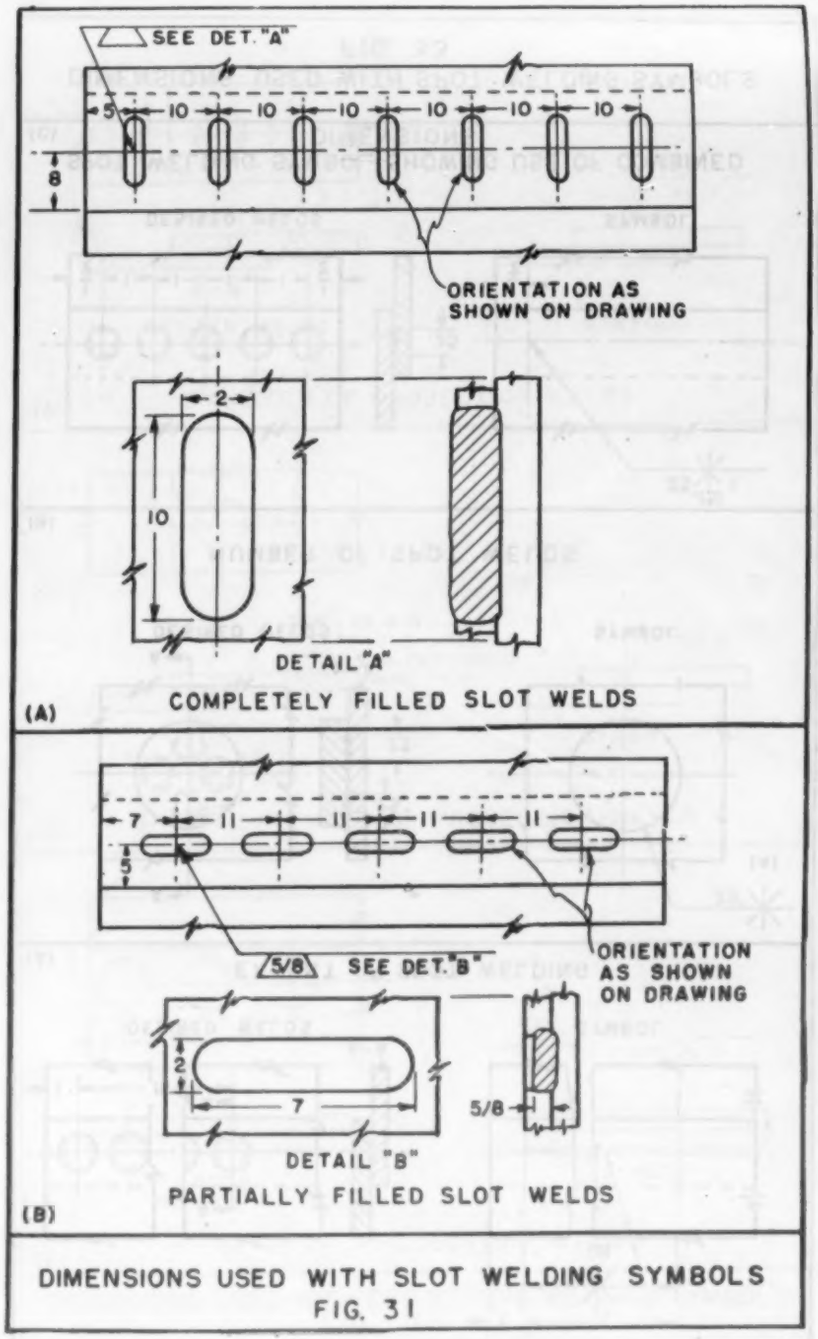
(B)

DIMENSIONS USED WITH FILLET AND GROOVE WELDING SYMBOLS

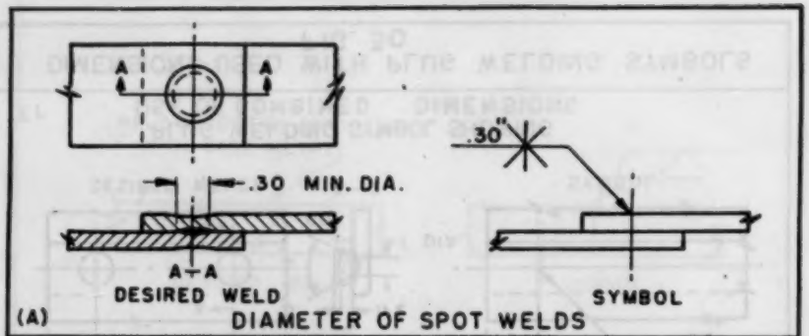
FIG. 29



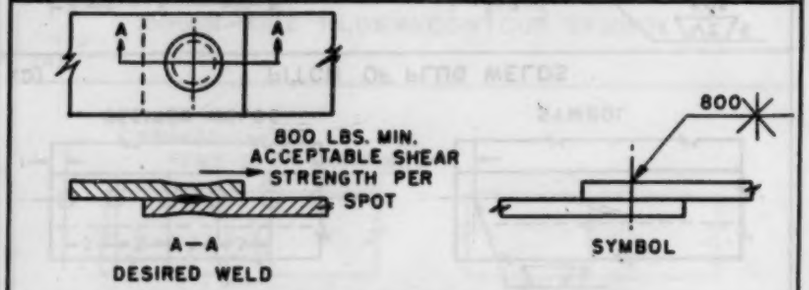
DIMENSIONS USED WITH PLUG WELDING SYMBOLS
FIG. 30



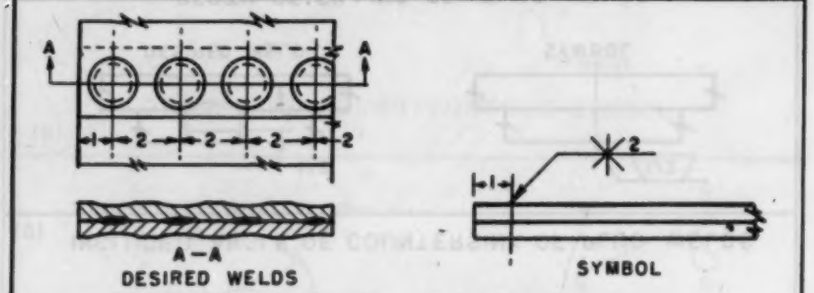
DIMENSIONS USED WITH SLOT WELDING SYMBOLS
FIG. 31



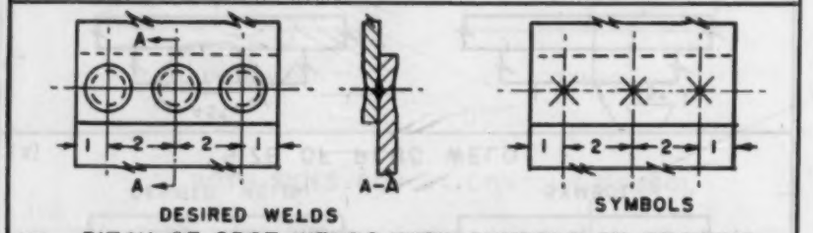
(A) DIAMETER OF SPOT WELDS



(B) SHEAR STRENGTH OF SPOT WELDS

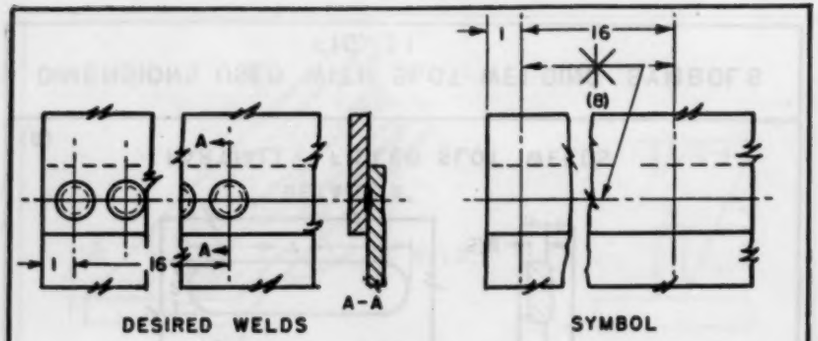


(C) PITCH OF SPOT WELDS SHOWN ON SYMBOL

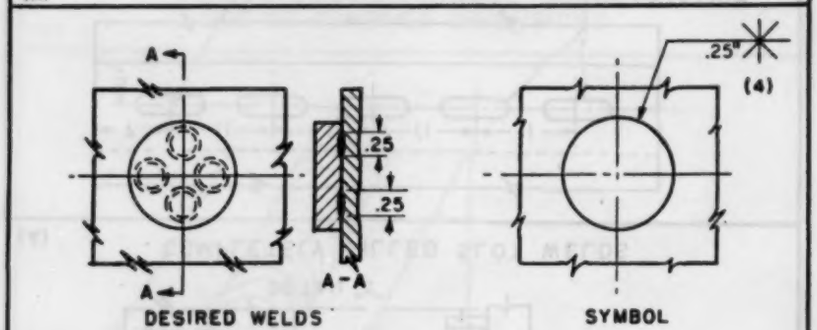


(D) PITCH OF SPOT WELDS WITH SYMBOLS ON DRAWING

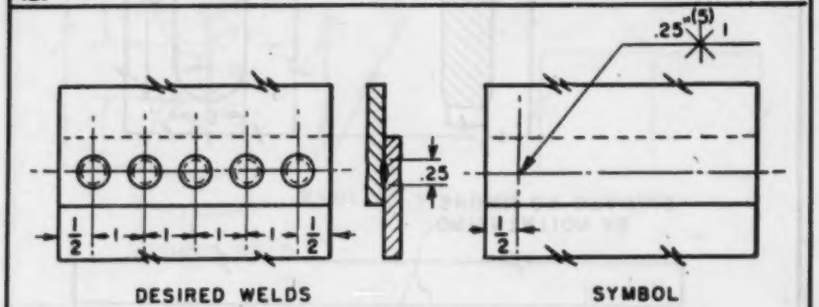
DIMENSIONS USED WITH SPOT WELDING SYMBOLS
FIG. 32



(A) EXTENT OF SPOT WELDING



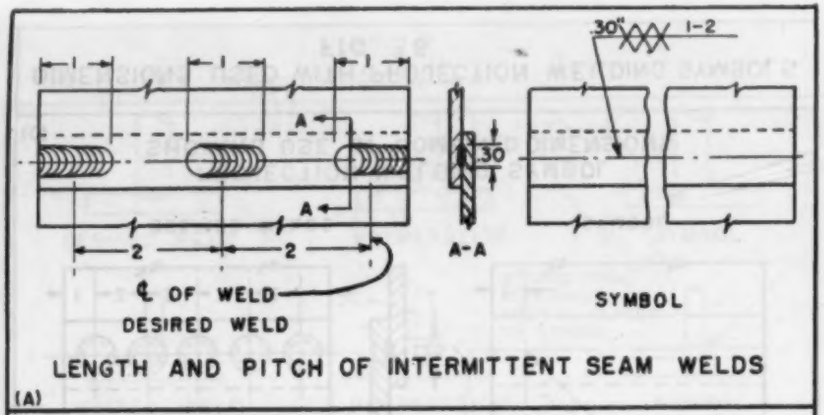
(B) NUMBER OF SPOT WELDS



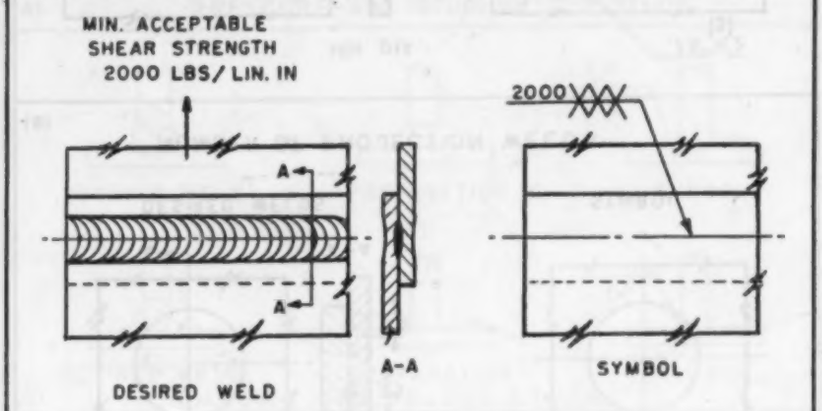
(C) SPOT WELDING SYMBOL SHOWING USE OF COMBINED DIMENSIONS

DIMENSIONS USED WITH SPOT WELDING SYMBOLS
FIG. 33

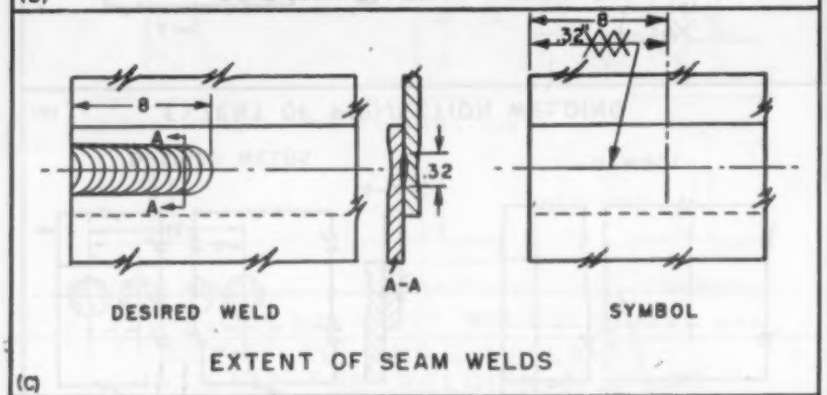
FIG. 32



(A) LENGTH AND PITCH OF INTERMITTENT SEAM WELDS

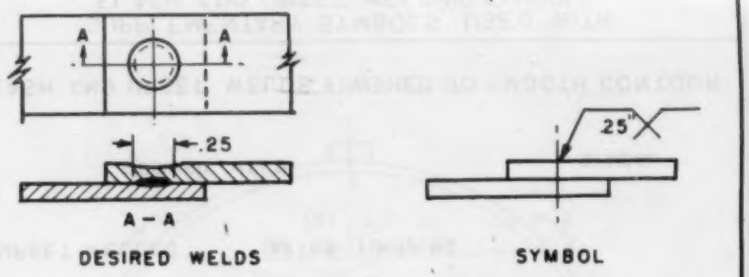


(B) STRENGTH OF SEAM WELDS

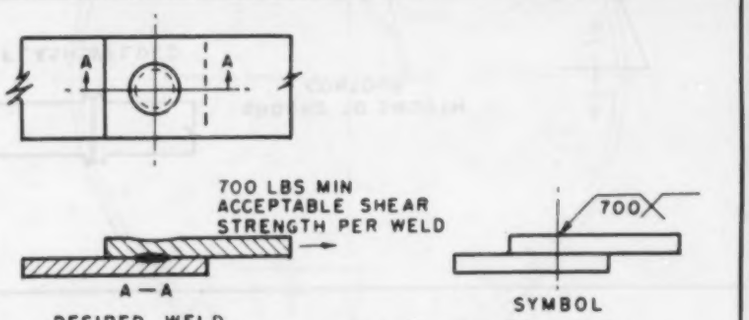


(C) EXTENT OF SEAM WELDS

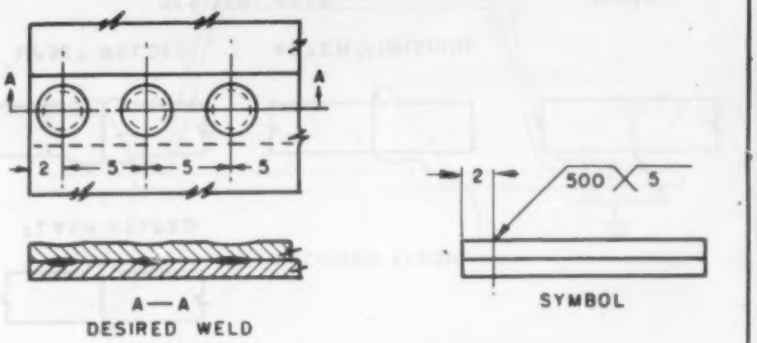
DIMENSIONS USED WITH SEAM WELDING SYMBOLS
FIG. 34



(A) DIAMETER OF PROJECTION WELDS

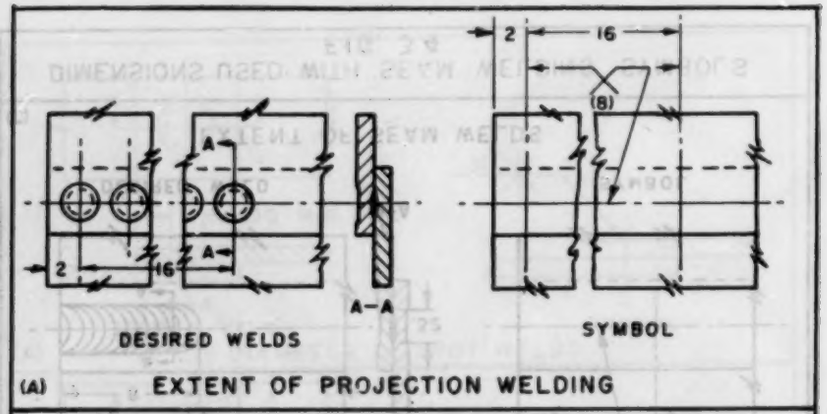


(B) SHEAR STRENGTH OF PROJECTION WELDS

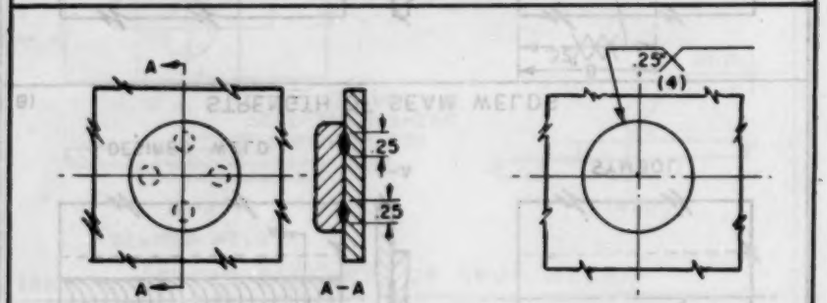


(C) PITCH OF PROJECTION WELDS

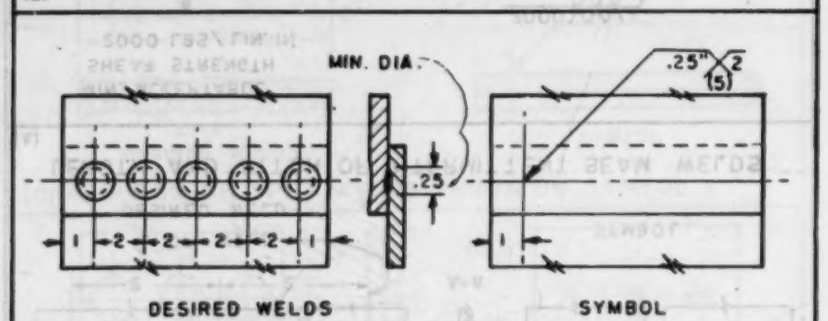
DIMENSIONS USED WITH PROJECTION WELDING SYMBOLS
FIG. 35



(A) EXTENT OF PROJECTION WELDING

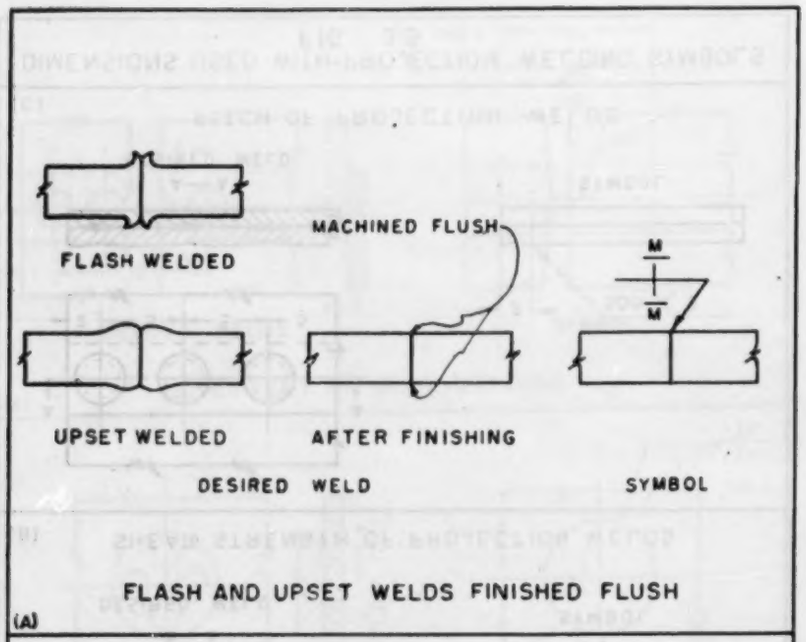


(B) NUMBER OF PROJECTION WELDS

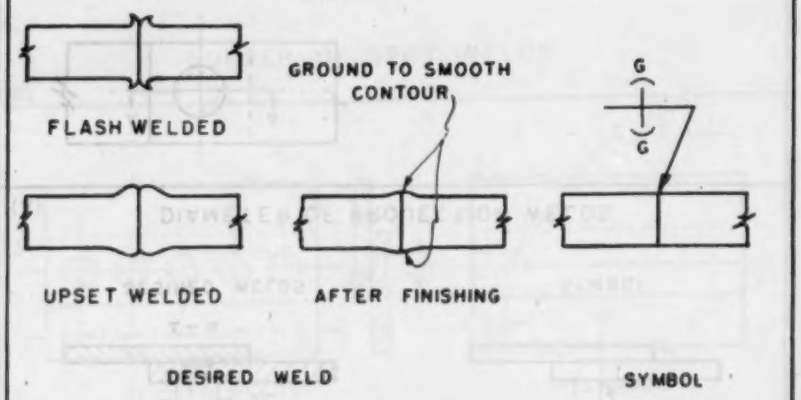


(C) PROJECTION WELDING SYMBOL SHOWING USE OF COMBINED DIMENSIONS

DIMENSIONS USED WITH PROJECTION WELDING SYMBOLS
FIG. 36

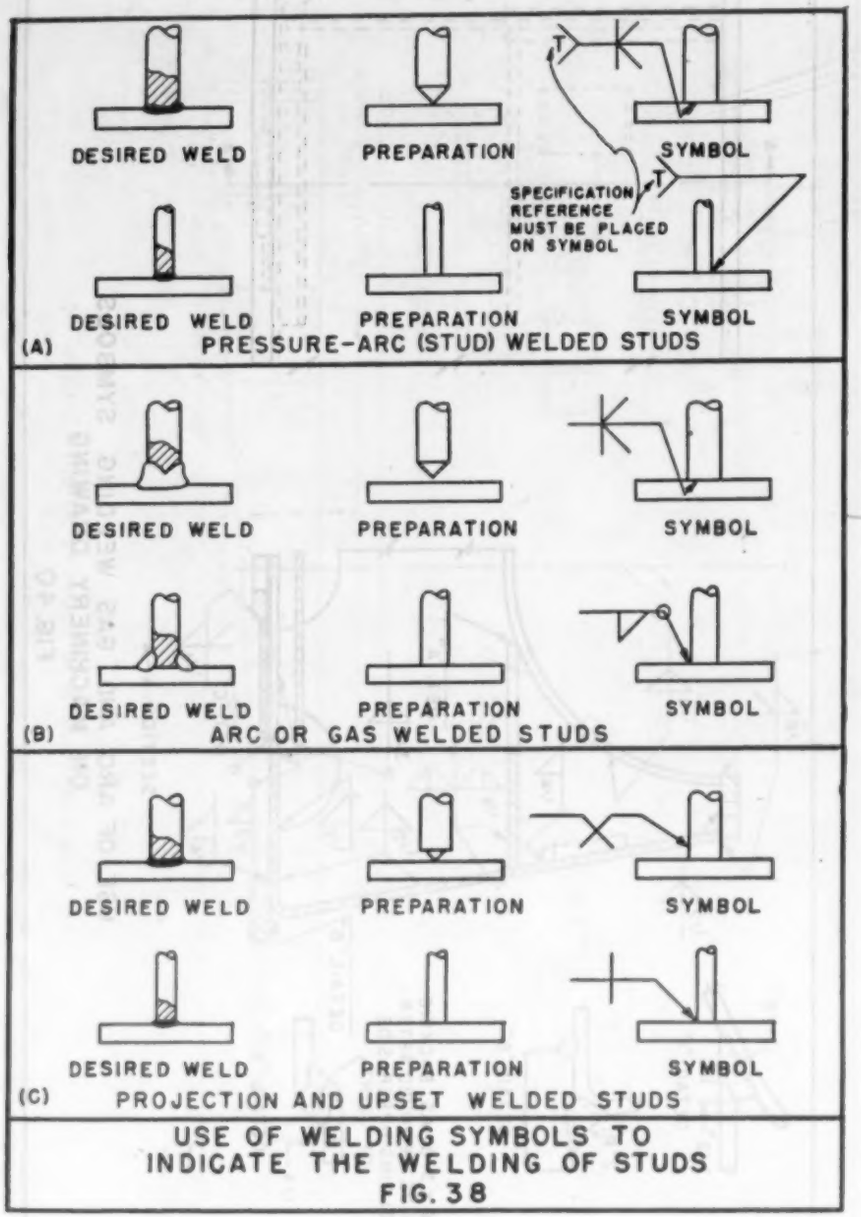


(A) FLASH AND UPSET WELDS FINISHED FLUSH



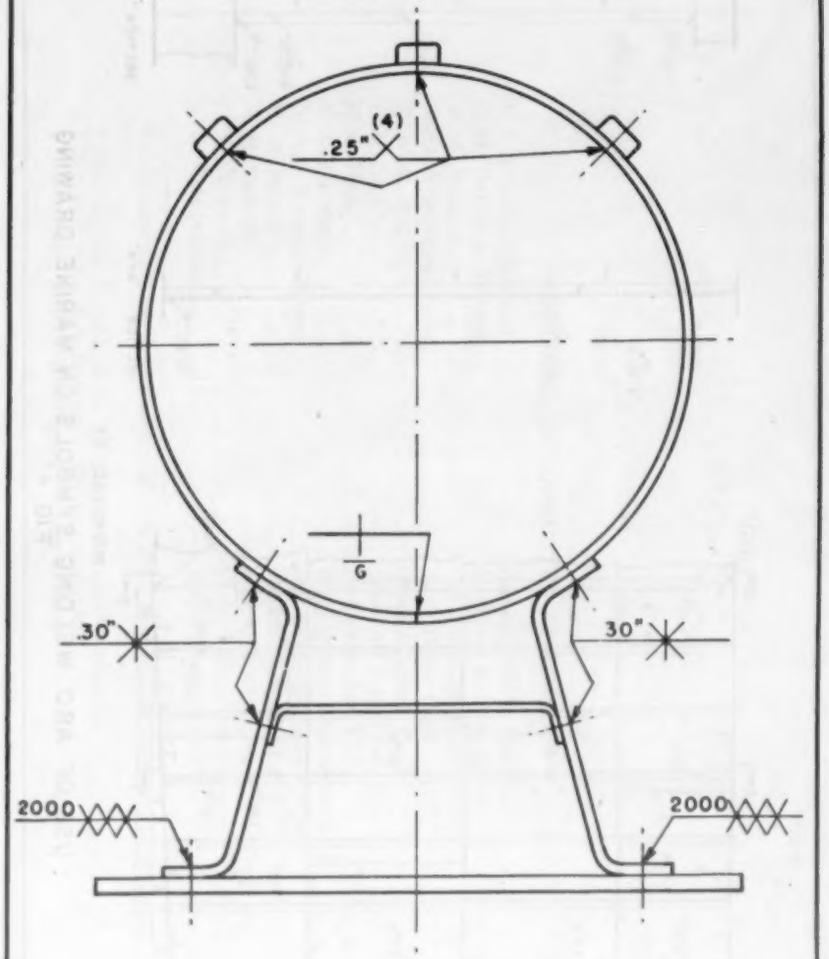
(B) FLASH AND UPSET WELDS FINISHED TO SMOOTH CONTOUR

SUPPLEMENTARY SYMBOLS USED WITH FLASH AND UPSET WELDING SYMBOLS
FIG. 37



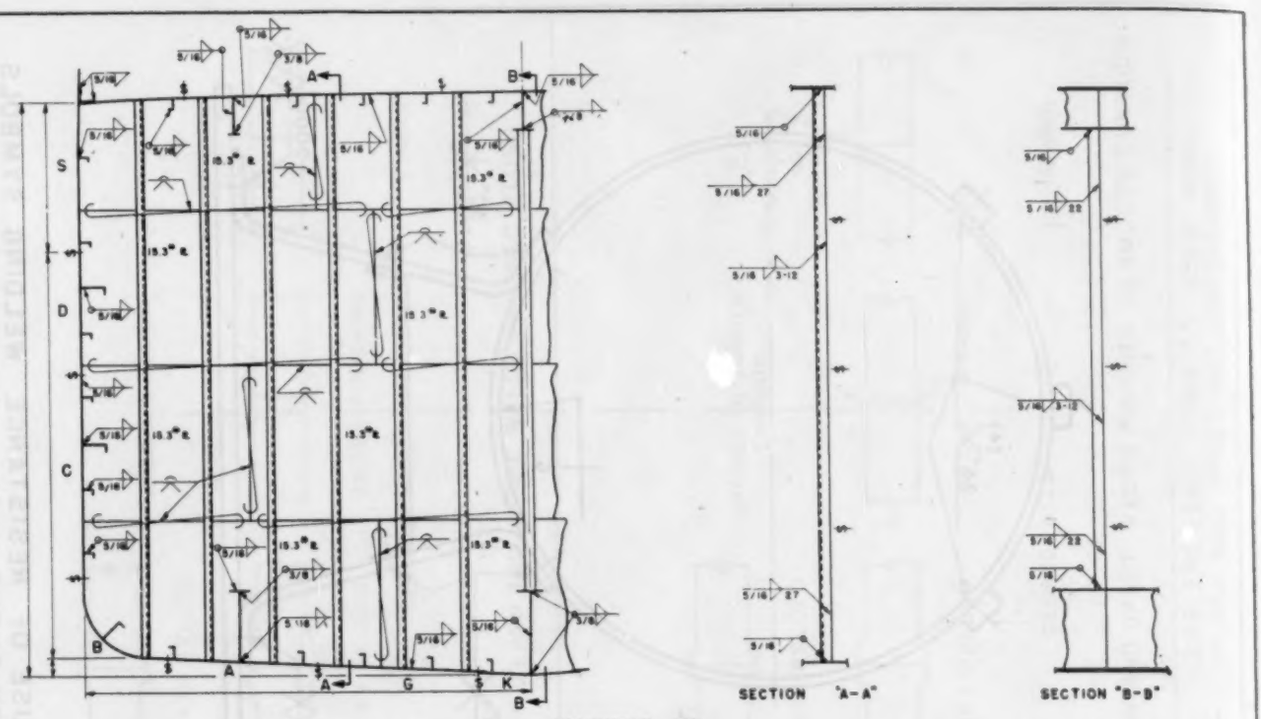
USE OF WELDING SYMBOLS TO INDICATE THE WELDING OF STUDS

FIG. 38

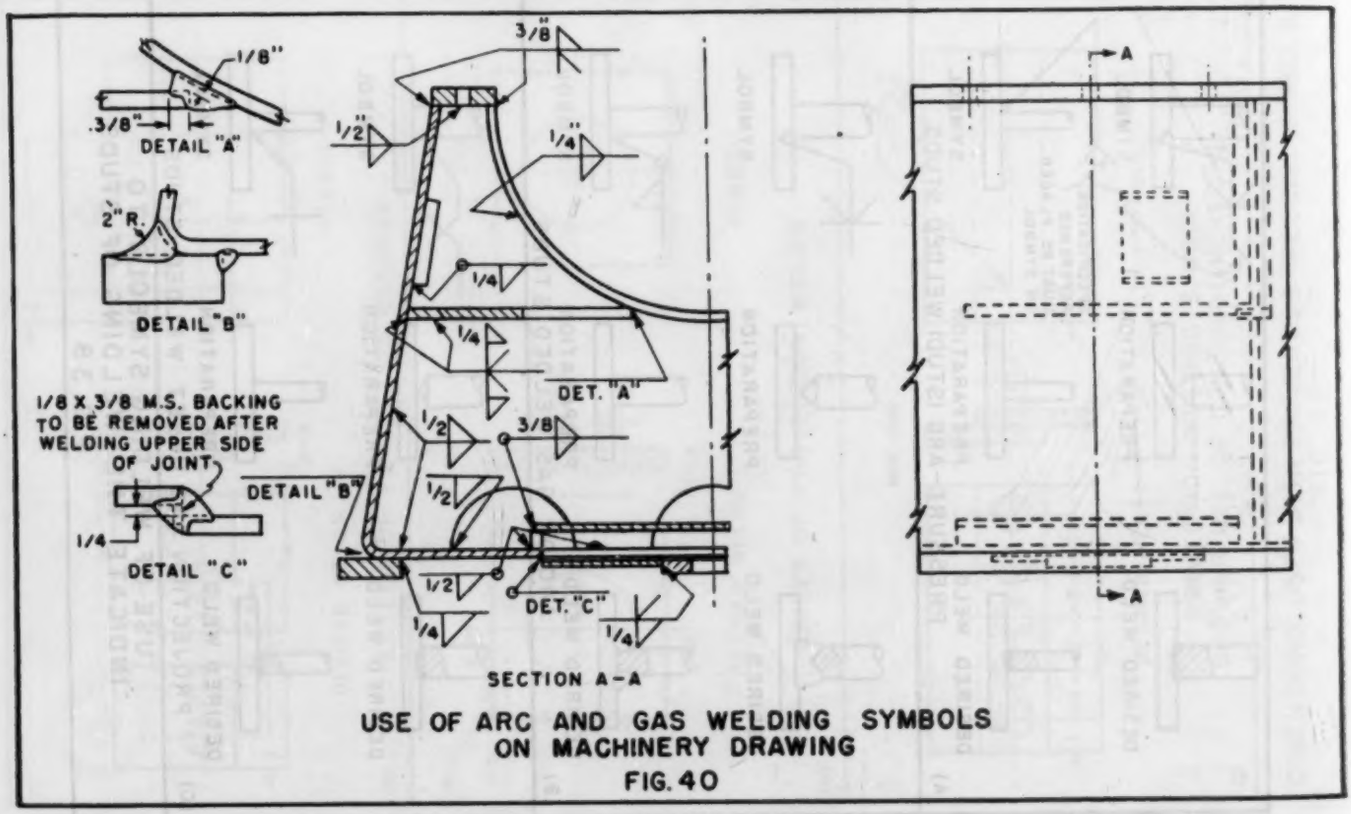


USE OF RESISTANCE WELDING SYMBOLS ON SHEET METAL FABRICATION DRAWING

FIG. 39



USE OF ARC WELDING SYMBOLS ON MARINE DRAWING
FIG. 41



USE OF ARC AND GAS WELDING SYMBOLS ON MACHINERY DRAWING
FIG. 40

PERSONNEL OF COMMITTEE ON SYMBOLS

L. C. BIBBER, *Chairman*.....Carnegie-Illinois Steel Corp.
L. M. DALCHER, *Secretary*.....American Welding Society
W. A. BISCHOFF.....Bell Telephone Laboratories
BUREAU OF SHIPS.....Navy Department
R. W. CLARK.....General Electric Co.
F. H. DILL*.....American Bridge Co.
H. O. HILL.....Bethlehem Steel Co.
C. H. JENNINGS.....Westinghouse Electric Corp.
A. B. S. KVALL, *Alternate*.....Bell Telephone Laboratories
H. M. PRIEST.....Railroad Research Bureau
H. H. TROGER†.....Federal Shipbuilding & Dry Dock Co.
C. B. VOLDRICH‡.....Battelle Memorial Institute
V. S. WIELOSINSKI§.....Willys-Overland Motors, Inc.

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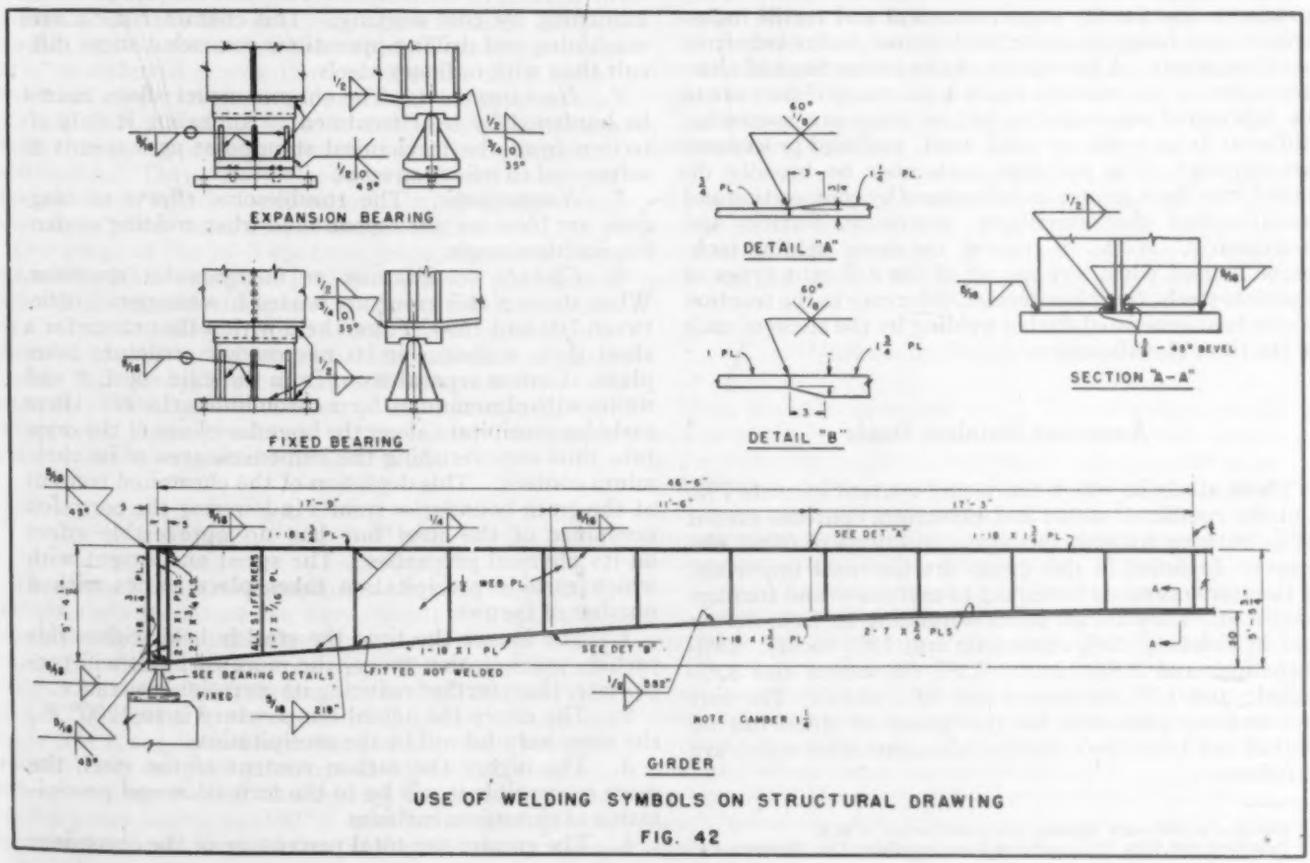
* Representing Conference Committee on Welded Bridges and Committee on Building Codes.
† Representing Committee on Welding in Marine Construction.
‡ Representing A.W.S. Resistance Welding Committee.
§ Representing A.W.S. Automotive Welding Committee.



USE OF WELDING SYMBOLS ON STRUCTURAL DRAWING

FIG. 42

Welding the Stainless Steels*

By J. L. Filbert†

THE corrosion-resistant or stainless steels as they are most generally known have come into more prominence during the past four or five years than ever before. An almost unlimited field of new applications for these steels has been developed due to a better understanding of their chemical and physical properties and also because of the fact that they are readily joined by the most satisfactory of all metal joining processes—welding. These steels cover a wide range of chemical compositions, within which may be found a type for almost every purpose. Because of their ability to withstand both chemical and atmospheric corrosion and oxidation, and to retain their resistance to fatigue, impact and wear at practically all temperatures, they are suitable for fabrication into many different types of equipment, such as tanks, piping, aircraft exhausts, heat exchangers, forging dies and synthetic-rubber processing equipment. Manufacturers of petroleum refinery equipment are fabricating reaction chambers, flash towers, evaporators, coking drums, vacuum towers, bubble towers and vapor lines out of various grades of stainless steel. Equipment for the processing of foods and dairy products, and for the paper, chemical and textile industries is now being manufactured almost exclusively from stainless steels. A knowledge of the properties and characteristics of the stainless steels is necessary if they are to be fabricated successfully, for, as they are somewhat different from ordinary mild steel, modified procedures are required. The stainless steels may be broadly divided into three groups as determined by composition and metallurgical characteristics; austenitic, ferritic and martensitic. While, in general, the same welding technique is used when welding all of the different types of stainless steels, there is a decided difference in the reaction to the heat generated during welding by the steels of each of the three classifications.

Austenitic Stainless Steels

Those steels in which the nickel content exceeds 7%, and the combined nickel and chromium contents exceed 24%, with or without moderate additions of other elements. Included in this group are the most important of the stainless steels in respect to usefulness and tonnage produced. They are the steels containing 18% chromium and 8% nickel; 25% chromium and 12% nickel; 25% chromium and 20% nickel; 15% chromium and 35% nickel; and 15% chromium and 60% nickel. The correct welding procedure for this group of steels can be worked out from their physical characteristics which are as follows:

1. *Thermal conductivity*—one-half that of mild steel. Heat of welding is concentrated in the area adjacent to the weld. Welding current settings should be regulated to produce just enough heat to effect good fusion so that distortion and the setting up of residual stresses will be held to a minimum.

2. *Thermal expansion*—50% greater than that of mild steel. Base metal will be subject to warping and distortion to a greater extent than mild steel, which must be controlled during welding.

3. *Electrical resistance*—six times greater in the annealed state and twelve times greater in the extremely cold-worked condition than mild steel.

Ten to twenty per cent lower welding currents should be used than when welding with mild steel electrodes of the same diameter.

4. *Melting temperature*—approximately 200° F. less than that of mild steel. Weld metal is much more fluid than mild steel at the same temperatures.

5. *As-welded condition*—They are suitable for welded construction since they require no subsequent heat treatment to remove brittleness. They are subject to severe hardening by cold working. This characteristic makes machining and drilling operations somewhat more difficult than with ordinary steels.

6. *Heat treatment.* The chrome-nickel alloys cannot be hardened by heat treatment. Annealing is only effective from the mechanical standpoint as a means to soften and to relieve stresses.

7. *Nonmagnetic.* The troublesome effects of magnetic arc blow are not encountered when welding austenitic stainless steels.

8. *Carbide precipitation or intergranular corrosion.* When steels of this group are heated to a temperature between 700 and 1500° F. and held within that range for a short time, a change in its microscopic structure takes place. Carbon separates out from the solid solution and unites with chromium to form chromium carbides. These carbides precipitate along the boundary lines of the crystals, thus impoverishing the immediate area of its chromium content. This depletion of the chromium content at the grain boundaries results in lowering the corrosion resistance of the steel but has no appreciable effect on its physical properties. The speed and extent with which carbide precipitation takes place varies with a number of factors:

1. The longer the time the steel is held within this carbide precipitation range, the more carbides will precipitate, thus, further reducing its corrosion resistance.

2. The closer the actual temperature is to 1200° F., the more harmful will be the precipitation.

3. The higher the carbon content of the steel, the more susceptible it will be to the formation and precipitation of chromium carbides.

4. The greater the total percentage of the chromium

* Presented at February Meeting, Louisville Section, A.W.S.
† Page Steel and Wire Div., American Chain and Cable Co., Monessen, Pa.

and nickel in comparison to the percentage of carbon, the less rapid the forming of carbides will be.

It must be remembered that there are a great many applications for which the austenitic stainless steels are used where a satisfactory degree of corrosion resistance will be maintained even though carbide precipitation has taken place during the fabrication of the steel. On the other hand there are many other very important industrial applications which demand the maximum degree of corrosion-resisting ability of which a stainless steel is capable.

Chromium carbides, after once being formed, can be removed only by reheating the steel to 1850 to 2100° F. when the carbides redissolve and the chromium and carbon go back into their original state in the alloy. The steel must be held at this temperature for a sufficient time for this action to take place. The steel must then be quickly cooled to below 600° F. within two or three minutes. This treatment may cause distortion of the material or may be impractical due to the size of the welded structure.

A great deal of study and investigation has been devoted to the control of carbide precipitation. While heat treatment is effective, it is not always practical or economical. It was recognized that if some element could be added to the welding rod or base metal analysis that would prevent the forming of chromium carbides, the problem of preserving the original corrosion-resisting qualities of the steel while under the welding heat, would be greatly simplified. Metallurgists have found that the addition of metals such as columbium and titanium would have this effect if they were added in amounts proportionate to the carbon content. These two metals prevent the formation of the chromium carbides, as they have a greater affinity for carbon than does chromium, and form their own carbides which are not harmful. Both are used in modified 18–8 stainless steels, but only columbium-modified steels are used in the manufacture of electrodes as it is practically impossible to transfer titanium across the arc; whereas, approximately 80% of the columbium content of the electrode can be satisfactorily transferred across the arc into the weld metal. Weldments operating at temperatures of between 700 and 1550° F. should always be fabricated of stainless steels containing proper percentages of either columbium or titanium. They should also be welded with a stainless steel electrode modified with columbium; the columbium content to be ten times the carbon content.

One grade of the 18–8 stainless steels, known as "free machining 18–8," contains 0.17% maximum phosphorus and 0.60% maximum sulphur for the purpose of increasing the machinability, instead of 0.025% maximum phosphorus and sulphur which is the usual content of these steels. It is strongly recommended that no attempt be made to weld this grade of steel, as the high sulphur and phosphorus content creates a "hot-short" condition which invariably results in cracked welds.

Ferritic Stainless Steels

These steels contain chromium in excess of about 16%, and the carbon content can vary from 0.12% maximum proportionately with the chromium content up to 0.35% maximum with or without small additions of other elements. The 16 to 18% chrome; 18 to 23% chrome; and 23 to 27% chrome types represent this class of stainless steels which are second in importance to the austenitic grades. They are used quite extensively in high temperature service up to 1800° in oxidizing atmospheres or hot sulphur gases, and up to 2100° F. in reducing atmospheres only, and in applications where resistance to the corrosive action of nitric acid, concentrated sulphuric acid, most alkalies, and hot gasses containing sulphur is necessary. They are expecially effective for these applications when the chromium content is over 25.00%. These steels may be welded by any of the methods recommended for the chrome-nickel steels, namely; metal-arc, oxyacetylene, atomic hydrogen, etc., but certain precautions should be taken because of their reaction to the heat of welding. A knowledge of their behavior under the influence of the heat of welding can easily be determined if their physical characteristics are known.

1. *Thermal conductivity*—one-half to two-thirds that of mild steel. Heat of welding is concentrated in the area adjacent to the weld which results in an increase in the grain size of the weld metal and in the zone adjacent to the weld causing brittleness. This brittleness may be reduced and the ductility can be improved by annealing, but as these classes of the straight chrome stainless steels are used primarily in applications involving operation at high temperatures, this procedure is not usually necessary as the problem is usually taken care of by the temperatures at which they operate.
2. *Thermal expansion*—about the same as mild steel. The extent of warping and distortion will be no greater than when welding ordinary mild steel.
3. *Electrical resistance*—five to six times that of mild steel. Welding currents should be a trifle higher than when welding the austenitic stainless steels and slightly lower than when welding ordinary mild steel.
4. *Melting point*—very slightly lower than mild steel. Weld metal will be of approximately the same consistency as the weld metal from a mild steel electrode.
5. *Air hardening*—do not air harden and can be only slightly hardened by quenching, and are hardened only moderately by cold working.
6. *Carbide precipitation*—these types of stainless steel are considered to be stable at all temperatures, consequently they are not subject to carbide precipitation. They are, however, subject to grain growth when used at temperatures above 1900° F. This can be reduced by the addition of carbon, manganese, nickel, copper, titanium or vanadium.
7. *They are magnetic*—magnetic arc blow is encountered when welding.
8. *Brittleness*—they become brittle and lose ductility when they are welded, and for these reasons require heat treatment for improvement of their physical properties. Long service at 800–950° F. make them brittle when cold, but they are not brittle at working temperature.

Martensitic Stainless Steels

These are iron-chromium steels, with or without small additions of alloying elements. These steels are ferritic in the annealed condition, but when cooled rapidly in air or in a liquid media from above the critical point, they are definitely hardened and hence called martensitic. The chromium content of these steels does not exceed 16% with a carbon content less than 0.40%. Typical analyses are 12 to 14% chromium; 8 to 10% chromium; and 4 to 6% chromium. These steels differ from the ferritic or austenitic stainless steels in that they are definitely hardenable when cooled rapidly from a high temperature. They are magnetic. The martensitic steels are capable of developing high physical strength and toughness, and are suitable for applications where those properties are desired and where requirements for corrosion resistance are not exacting. However, they offer good resistance to corrosion from the atmosphere, fresh water, steam and many organic and inorganic corrodents. These grades

are recommended for furnace parts operating up to 1200° F., coal chutes, mining equipment, construction equipment, cutlery and other similar applications. They retain their tensile properties at temperatures up to 750° F.

The same precautions must be taken when welding these steels as when welding the ferritic steels since their reaction under the heat of welding is practically the same with the one exception that the welds and base metal adjacent to the welds will be very hard and brittle due to their air-hardening characteristics. This air-hardening condition can be checked when arc welding these steels by preheating to a temperature between 300 and 400° F. Cooling should be controlled, and wherever possible, the welded structure should be annealed between 1300 and 1450° F. and slowly cooled after the welding operation.

Application of Welding on the Railroads

By Leland E. Grant*

THE art of welding, with the exception of forge welding and the Thermit process, has grown from its very beginning to the present extensive applications, all within the working span of many railroad welders. In fact, the railroads were the first industry to adopt welding and in its infancy it was considered so hazardous an occupation that it was necessary to pay the men a differential rate to persuade them to undertake it. Welding was initially done by the oxyacetylene process and was a convenient and rapid means for repairing leaks in fireboxes. From this simple beginning welding has grown to the industrial necessity it has now become and it appears desirable to consider its present-day applications on the railroads and possible future applications. Although the railroads were the first industry to adopt welding they have not, unfortunately, maintained this leadership although welding and welding processes are now used extensively by practically all railroads of any importance. Welding processes other than the oxyacetylene method are now in use; the electric arc has displaced the gas torch to a very great extent and the submerged arc, as well as methods of resistance welding are now in daily use. Applications of welding on the railroads range from the repair of small hand tools and other parts to the construction of cars and locomotives.

Modern locomotives have many applications of welding. The successful fabrication of locomotive cylinders, wheels, crossheads, guide yokes and various other parts from steel plates as substitutes for steel castings received considerable impetus from the shortage of castings during the war. It can be expected that further developments of this type will be forthcoming in the future. Light weight, low cost and, in some cases, more satisfactory parts are the chief motivating factors in this kind of development.

Locomotive boilers are not yet regularly fabricated by welding although one welded boiler has been in service for approximately seven years and requests for permission to build several others have been granted by the Interstate Commerce Commission. Locomotive boilers built in the United States for railroads in foreign countries have been partially welded so that it appears logical that welded boilers will be standard in the not too distant future.

The limitations involved in riveting practices appear to make it impractical to meet satisfactorily the requirements for high-pressure locomotive boilers with this method of construction which is, of course, a repetition of the history of pressure vessels for the petroleum and chemical industries. Yet the demand for economy in steam locomotive operation practically forces the adoption of still higher pressures in the boilers.

Welded boilers can be made lighter in weight than riveted boilers and do not offer the potential source for embrittlement that the riveted boiler does. It also seems very probable that welded boilers will be cheaper than the riveted ones, once the manufacturers have acquired the necessary equipment and "know-how" for making them. The success of welding as applied to stationary boilers and in petroleum and chemical equipment, as well as in the one welded locomotive boiler that is now in operation, gives reasonable assurance that welded locomotive boilers will be entirely satisfactory for the railroads.

Welded fireboxes on locomotives have been common for many years but in this case the conditions are somewhat different from the boiler itself because the load is carried very largely by staybolts and not solely by the weld. Locomotive tenders are also now fabricated by welding with the exception of the water bottom which is a single steel casting. The internal baffle plates of tenders are attached by welds to Tee irons or angles and this particular application furnishes a severe test of the ability of welded construction to serve satisfactorily because the surging of the water in the larger tenders puts extremely heavy loads on these plates and will cause failures of the welds if precautions are not taken to eliminate common defects such as undercutting, unfilled craters, poor fusions, undersized or lopsided welds.

The water bottoms of the tenders are not yet fabricated by welding but nevertheless require a certain amount of welding since these large castings usually contain numerous defects, both large and small, which can be satisfactorily repaired by welding. Such large castings cannot be scrapped without heavy economic loss and in any event defects can normally be welded so as to make the casting just as serviceable as if the defect had never existed.

Some Diesel locomotives have cast steel underframes. Others have frames fabricated, frequently by the submerged melt welding process, from heavy plate. Such frames have proved entirely satisfactory in severe service. Manual welding is used extensively in fabricating Diesel engine blocks and spot welding is a fairly common practice for fabricating the cabs and other parts made of thin sheets for this type of locomotive.

The construction of freight and passenger cars entirely by welding, except for safety appliances, is not now uncommon and evidence of this trend becoming more general is to be found in the new installations being made by the railroads to provide for welding in place of riveting for new construction. Private car builders are also doing

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more and more of their construction by welding. Many special types of cars are so built as well as the more conventional cars. This is a subject that needs the application of good welding engineering because there is definite evidence that much more welding is being applied on new cars than is required. Maximum economy in construction combined with good serviceability will be obtained only when the welding is properly engineered.

On the Milwaukee Railroad it has been the practice for a number of years to build passenger cars, freight cars and cabooses by welding. Merchandise cars which conform to the general lines of pasenger cars and operated in passenger trains have also been fabricated by welding on this railroad. The superstructure is fabricated by a combination of spot and arc welding; the underframes and trucks by manual arc welding. Ingot cars, hot metal cars, special well cars, covered hopper cars, snow plows and other special equipment have all been built by welding. As in the case of locomotive boilers, here, too, some of the incentives for the use of welding are low cost and light weight.

The use of all-welded freight cars necessarily leads to repairing these cars by welding and once a car yard has been equipped for repairing cars by welding it is to be expected that this method will also be applied to riveted cars wherever possible. This has been done extensively in the past.

There are some problems in the use of welding on a riveted type of car which must be given consideration if satisfactory results are to be obtained. Riveting permits a certain amount of movement of the parts, welding does not; as a result, the rigidity developed by welding causes unexpected subsequent failures. Occasionally one sees examples where loose rivets have been welded around the head to make them tight and thus eliminate the necessity for replacing them. This cannot be done satisfactorily because the amount of weld that can be applied is too small to carry the load successfully and in a short time the working of the rivets causes the weld to break and the rivet will be loose again. If the rivets are not replaced with new ones properly driven, the proper procedure is to weld the parts themselves together instead of trying to weld the rivets. The rivets may then be tacked to keep them from rattling.

Welding processes offer a fast and convenient method of repairing broken posts, braces, cracked or torn side and roof sheets and also permit the making of satisfactory repairs to broken center and side sills without extensive dismantling of the car. Welding, of course, is used extensively in repairing individual parts of the cars such as yokes, couplers, side frames, bolsters and center plates within A.A.R. limitations. Much of this kind of work is done at reclamation points where the parts can be taken out to be properly welded and subsequently heat treated, if necessary, to restore their initial properties.

During the war years this was a means of saving large numbers of castings which would otherwise have had to be replaced. Most railroads have reclamation shops where not only car parts but locomotive parts and other material are reclaimed, primarily by applications of various welded processes. Rebuilding of worn bearing surfaces, locomotive pistons for example, is commonly done with some grade of bronze using the oxyacetylene process. Brazing broken parts made of cast iron such as locomotive cylinders, air pumps and machinery parts saves the railroads large sums of money annually.

Only in comparatively recent years has welding been applied to maintenance of way work but at the present time it is quite common practice to weld up chipped rail ends and to rebuild worn frogs. This type of welding is in general done on high-carbon steel or in the case of frogs and crossings possibly manganese steel and under conditions which are not ideal for welding. Although this kind of welding appears undesirable from a metallurgical point of view it, nevertheless, has been satisfactory and adequate and has greatly extended the useful life of both rails and frogs.

Recent developments in alloy rods have provided a means of welding frogs to give much longer life than was possible with either the ordinary low-carbon rods or plain high-carbon welding rods. The alloy rod is somewhat more expensive than the plain-carbon ones but the greatly increased service life much more than offsets the additional cost. Incidentally, the cost of the electrode for repairing a worn frog is only a small part of the total cost.

Welding is also being applied to strengthening bridges, although up to the present time welding has been used for the fabrication of entire railroad bridges to the same extent as in European practice.

Much maintenance of way equipment such as spreaders, ditchers, cranes, buckets, tractors, etc., is repaired and kept in serviceable condition by welding. The application of rods with good wear resistance is an important part of such work. Hard surfacing is also applied on certain track tools such as tie tamper blades to lengthen their effective life.

From the above rather brief and sketchy picture of the applications of welding on the railroads it is apparent that it is a very vital process in not only maintaining equipment but also in building new equipment. The advantages are so numerous that it is certainly a safe prediction that welding will be increasingly used by the railroads. It must, however, have effective safeguards. Many lives and valuable equipment are involved and carelessness or poor workmanship should not be tolerated. The railroads can and should take effective steps to insure good welding in the more important parts. The American Association of Railroads has set up certain limitations on welding to prevent misapplication. Many of these probably would not be necessary had welding always been done by competent operators. It is realized that to safeguard railroad welding adequately is a difficult job but this is not a satisfactory reason for shirking it. The benefits derived from welding are so great that the cost of providing suitable inspection and other safeguards can be completely justified.

Modern Steels in Railroad Construction*

By H. Malcolm Priest†

RAILROADS and steel have long been intimately associated. The growth and development of one has paralleled that of the other, and both have been a powerful influence in the progress of the United States.

This year marks the 100th anniversary of the Pennsylvania Railroad. Let us take just a moment to glance backward to 1846. Pittsburgh was a growing community with a population of about 40,000. That year saw the establishment of telegraphic communication with the East when the first message was sent from Pittsburgh, Dec. 29, 1846. It was a report to President Polk that the Second Pennsylvania Regiment was nearly ready to leave for Mexico. Leland D. Baldwin, in his book *Pittsburgh—The Story of a City* states that the *Post* was the first newspaper to utilize the telegraph when in 1847 it began the publication each morning of a column of dispatches captioned "Received by Lightning, Printed by Steam."

Twenty states, all west of the Mississippi River, were still to join the Union and not a mile of railroad existed in that vast territory. In the year 1850 there were only 8683 miles of railroad. The Pennsylvania Railroad was opened to through traffic between Philadelphia and Pittsburgh on Nov. 29, 1852, and two years later there were 3 trains each way a day, requiring from 13 to 17 hours to make the journey. The country stood on the threshold of a great era of vast expansion and history records the part that the railroads played in building this nation to its present eminence.

Over the years, the railroads have taken a large percentage of the total production of the steel industry. An almost endless number of products of steel find their way into railroad operation. Obviously, the complete story cannot be told in one short paper. Much of the story is familiar to all, but research and new operating demands have brought about developments in steel which may be of especial interest.

Let us begin this story of steel with the rails. Higher speeds of operation and heavier locomotives to haul longer and heavier trains have put an increasing burden on track. Just 50 years ago, in the *Scientific American* of Jan. 18, 1896, there appeared an interesting editorial entitled "The Acceleration of Railway Speeds." It was only 3 years prior to that time, in 1893, that the Empire State Express had run for a short distance at over 100 mph. The editorial forecast that the 20th century would see a demand from the public for higher speeds, and proceeded to list the improvements in track and equipment that would be needed.

Among these changes was listed the need for heavier rail. That change has taken place. The catalog of "Sections for Steel Rails" published in 1895 by the Carnegie Steel Co., Ltd., listed the rails purchased by various railroads. It is interesting to look through this old catalog and to see that the heaviest rail section purchased by the Pennsylvania Lines, for example, was 80 lb. per yard; also 80 lb. for the B. & O. R.R. and the P. & L. E. R.R., and 90 lb. for the New York, Lake Erie and Western R.R. Twenty-five years ago, only about 15% of the mileage was of rails heavier than 90 lb. per yard, whereas, today, the percentage has risen to nearly 50. About 31,000 miles of main line track on Class I railroads now have rails heavier than 130 lb. per yard.

Research has been, and continues to be, unremitting in its endeavor to improve the quality of the steel in rails. Chemical composition has been studied from every standpoint in this high-carbon material, and the functions of the various alloying elements have been carefully appraised. In the open-hearth department, the steel-making practice as applied to rail heats has developed into a specialty controlled with meticulous care. Results of improvements in rail manufacture in the last decade are illustrated by American Railway Engineering Association data which show an average of 3.6 failures per 100 average track-miles after two years' service on rails produced in 1940 and 1941, as compared to 12.7 failures after two years' service on rails produced in 1933 and 1934. If the data were weighed against the tonnage carried, the present-day experience would be even more impressive. The impact properties of a rail are unquestionably one of its most important characteristics and these have been improved by a major change in open-hearth processing. Transverse fissures in rails have almost disappeared as a result of the heat-treatment process known as the controlled or slow cooling of the finished rail as it cools to atmospheric temperature from the rolling heat. The search for methods of production that will result in an even better rail is being pursued continually.

A Joint Committee of the Mechanical and Engineering Division of the Association of American Railroads is conducting studies and tests on the relation between track and equipment. The heavier power units and high speeds have overloaded the steel in rails. At the University of Illinois, the committee has been investigating the relation between the load and area of contact which is affected by the diameter of the wheel and the shape of the rail head. Another investigation of the Joint Committee is concerned with the impact effect of flat wheels. From these and other activities, one sees how extensive and thorough are the researches looking to better rails and the improvement of conditions under which they function.

There are several developments in the field of freight and passenger cars which warrant attention. We may well begin with the wheels and axles.

There has been progressive improvement in the manufacture of axles over the last decade. The efforts of the mill have been to refine the steel-making, forging and

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heat-treating processes, with the result that the axles of the present day are much superior to those of 10 years ago.

The majority of axle failures in the past have been traced to machine work; such as tool marks and chatter marks, poor journals, scored and overheated journals, and overloading, but the main cause of failure has been in insufficient area of cross section and inadequate design; that is, inadequate for present-day speeds and loads.

An extensive investigation conducted by the Mechanical Division of the Association of American Railroads has resulted in the redesign of all passenger and tender axles. Fatigue failures have been reduced to a minimum by the removal of the collar back of the wheel seat and an increase in the diameter of the wheel seat. Adoption and application of standard designs for axles has been the main effort of the manufacturer and the railroad user. The Association has now standardized all roller bearing axles, and one type can be used for all designs of roller bearings.

The making of steel wheels is one of the novel operations in a steel mill. The main classes of wheels are the one-wear wrought steel wheels produced for freight car use only, and the multiple-wear wrought steel wheels used for engine trailer, engine tender, passenger car and Diesel locomotive service.

A continuous metallurgical research and development program on rails, axles and wheels over the past 10 years has resulted in significant enhancement of the properties of these products which is reflected in longer life, superior performance and, above all, greater safety. Probably the most important metallurgical improvement, beyond that of the steel-making practice, has been the development and general application of a controlled cooling practice after the forging or rolling of these products. The previous practice of air cooling resulted in residual stresses which were often of such magnitude as to cause the formation of internal cracks. These cracks were propagated and opened up further by the strains imposed by service and were occasional causes of failures in rails and wheels. The controlled slow cooling after forging or rolling which has now been generally adopted results in very greatly reduced cooling stresses, and the danger of failure from this cause has been virtually eliminated.

An innumerable variety of wire products are to be found in and around railroad property. A vitally important factor in the operation of the signal track circuits is the rail bonds. They fall into two classifications: those for application to the head of the rail and those spanning the rail joints and attached to the rail web. Power bonds vary considerably in size, depending upon the voltage of the electrified system. They are for use both on track rail and third rail and usually function also as signal bonds.

Miles and miles of galvanized wire fence, barbed wire and steel telegraph wires stretch along the right of way. Nails, small in themselves, are one of the most universally used products of wire. Wherever loads are to be lifted, there will be seen wire ropes, the sinews of all lifting equipment. Concrete conceals buried rods and wire mesh that reinforce the structure. Every passenger car carries hidden wiring in generators, motors and lighting circuits. This short list of applications could be expanded without difficulty.

The average traveler on the railroads seldom sees the tubular products that are produced by the steel industry. He may be conscious of the hand rails on stairs, ramps and bridges, placed there for his personal safety, or he may notice the steel pipe in the mechanical interlocking type of signal systems, or poles for signals, semaphores and the like. It is less evident that every freight car has air brake piping, or that passenger cars have additional pipes for steam and water lines and air conditioning equipment. Stations, power plants, cold storage plants and other buildings have large quantities of tubular products hidden behind walls and under floors.

One of the most important applications of seamless tubes is in the boilers of locomotives. Here dependable, uniform physical properties are essential and so these tubes require careful metallurgical supervision over every phase of the manufacturing process. Every boiler tube is thoroughly annealed as a final operation to impart uniformity of internal structure and to improve the fabrication qualities.

In the central power stations that furnish electricity for railroad uses, higher operating pressures and superheating of steam have emphasized the subject of creep. It has been found that under static loads, metals flow at stresses which are much less than the short-time strength at similar temperatures. Creep load values are usually designated as the limiting load which may be applied for a certain time, say 10,000 hours at a certain temperature without producing more than 1% elongation. Special steels had to be found that would perform satisfactorily under these conditions.

This might be called the era of light weight construction in the transportation industry. The 50-year-old editorial in the *Scientific American* stated that "It is in the reconstruction of cars that the greatest gain will be made." Continuing, the editorial called for the lightening of cars in their construction by the substitution of high-grade steel for timber, and proposed the use of an alloy steel for the floors and side trusses, with thin plating for sides and roof. That call for light-weight construction is being answered today and is being accomplished in large measure by the use of "high-grade" steels. Technical progress in design, coupled with these new steels, is producing the modern streamliners and light-weight individual passenger cars. Dead weight of freight equipment likewise is being reduced and pay load increased.

A glance through the *Car Builders' Encyclopedia* of 1931 shows that representative steel-sheathed 50-ton box cars average 47,000 lb. in weight. The same type of car, using high-strength low-alloy steel in its construction, has been produced at a weight of 36,000 to 37,000 lb., a difference of about 5 tons. The standard A.A.R. design of 50-ton hopper car will weigh around 41,000 lb. In contrast, the light-weight car of high-strength steel has been built to weigh as low as 30,000 lb., with the average weight around 34,000 to 35,000 lb.

Welding is being utilized to an increasing extent in the fabrication of all classes of cars. It provides opportunities for new types of joints that eliminate overlapping seams and shelves where dirt can accumulate and retain moisture. In some instances, the entire car body is welded; in others, subassemblies are welded and are then riveted together in the finished car.

Stainless steel in some of the streamlined trains is familiar to all, but there may be other applications of stainless steel in the railroad field that are not as well known. A recent novel application is in a covered hopper type of car for the bulk transportation of sugar, and the same car is applicable for the shipment of flour. Tank cars of stainless steel have been used for a long time in the transportation of corrosive materials, but now a large chemical company is shipping plastic primaries in such cars to avoid any possibility of contamination that would affect the color. Candy makers, bakers and ice cream companies use liquid instead of granulated sugar, shipping it in stainless steel tank cars. Milk has long been shipped in stainless steel tanks in refrigerator cars. Stainless steel is utilized in decorative work and

in the trim of passenger cars because of the ease of forming it and its attractive color. It is a very usable material, but has its own peculiarities, due to its high strength, toughness and extreme ductility. It is customarily fabricated on the same equipment and by the same methods normally used for similar operations on plain steel. Occasionally slight modification of cutting or clearance angles may be found necessary when turning, drilling, tapping and so forth.

The past decade has seen the development of the class of steels known as low-alloy, high-strength steels, and they have had a widening influence on railroad passenger and freight car construction. Such a steel, for example, introduced by the United States Steel Corp. in 1934, under the trade name of U.S.S. Cor-Ten, has already been built into over 62,000 freight cars and 2500 passenger cars of American railroads. It has also gone into Australian railroad cars and is now being introduced into British equipment by licensees in England.

What are the characteristics of this steel which account for this record? The designation is suggestive of the answer: high strength, obtained with low percentages of carefully selected alloys. The steel is used in the as-rolled condition and does not depend upon heat treatment for its enhanced strength. Coupled with the high strength is a marked increase in resistance to corrosion, an attribute of vital importance. This steel has given a good account of itself in service where, at times, it has come in contact with hot lading. Under the action of such lading as coke, it has shown distinctly better resistance to abrasion than plain steel.

Fabricating methods are the same for high-strength as for plain-carbon steel with the one exception that in cold pressing operations it has been found desirable to use a larger radius in the fillets.

To understand more fully how these properties of low-alloy, high-strength steel are utilized, it may be helpful to discuss very briefly a few principles of engineering design and the behavior of steel under stress.

Popular experience is not likely to lead to the conclusion that steel is elastic, yet elasticity is one of the most important characteristics of steel and other metals. It is difficult to show the elasticity of a short bar of steel because of the minute change in length that takes place when we pull or compress the bar. However, by using a coiled spring of steel one can, in effect, magnify the elastic distortion until it is quite evident. Up to a certain load it will be found that the spring will return to its original length when the load is removed. There comes a time, as the load is increased, when this is no longer true and the spring remains permanently stretched or, as we say, it has a permanent set.

Coming back to a bar of ordinary structural carbon steel, we find that when we subject it to an increasing pull, the bar elongates elastically up to a certain point and beyond that point elongates rapidly with no increase of load. When the load is removed it is found that the bar has received a permanent set. The point at which this change takes place is known as the yield point. For the plain steel, the yield point is around a stress of 33,000 psi. The high-strength, low-alloy steels have a yield point of 50,000 psi., or 50% more than that of plain steel. Herein lies the chief feature of this group of steels. For successful weight reduction, however, the added strength must be coupled with high resistance to corrosion.

The yield point is obviously a limiting stress, for beyond that limit any structure will receive permanent and highly undesirable and perhaps even dangerous deformations. Working stresses, or the design stresses, used by engineers are, therefore, based upon the yield point of the steel with a suitable factor of safety. When a steel can be used at higher working stresses, less of it is required to perform its function in a structure. The 50% increase in yield points of the high-strength steels enables a designer to effect reductions in weight of about one-third under the most favorable conditions. In other words, 2 lb. of high-strength steel can do the work of 3 lb. of ordinary steel. Actual experience and practice have shown that weight savings will average about 25%. The cost of high-strength steel relative to that of copper steel is such that this weight reduction goes far toward equalizing the cost of the two steels in a completed structure.

The weight-saving possibilities of high-strength steel are being utilized more and more extensively in railroad freight and passenger equipment. The underframe, sides, ends and roofs, in fact, the entire car body structure, share in the weight reduction. The reasons for this increase in light-weight construction and the advantages to be obtained are many.

The reduced thickness of material in high-strength steel makes it essential in most instances that the steel have increased resistance to corrosion in order to maintain or surpass the life obtained with plain or copper steels. A good example of the value of corrosion resistance has been developed from the 100 light-weight hopper cars built by the Pressed Steel Car Co. in 1935 and for the last 11 years in service on the Bessemer & Lake Erie Railroad. In these cars the sides were $^{3}/_{32}$ in. in high-strength steel as compared to $^{3}/_{16}$ in. in plain steel designs and the slope sheets varied from $^{3}/_{32}$ in. at the top to $^{5}/_{32}$ in. in the hoppers, against $^{1}/_{4}$ in. in plain steel. With material one-half as thick, the high-strength steel used in these cars is still giving an excellent account of itself.

Design engineers are often concerned with the deflection of structures. Deflection takes place because the material is elastic. From tests, it is possible to determine a property of the material known as the modulus of elasticity which is a determining factor in deflection. Without going into any technical discourse, it will be enough to say that the lower the modulus of elasticity, the greater will be the deflection under a given condition. Here, for example, are a few typical values for different materials:

Material	Modulus of Elasticity, Psi.
Yellow pine	1,600,000
Magnesium alloys	6,500,000
Aluminum alloys	10,300,000
Steel	29,000,000

Section for section, steel will have much less deflection than any of the other materials.

Engineers are interested in another contribution of research, which, in recent years, has brought an increasing awareness of the importance of stress concentration at sharp corners, fillets, notches and other types of discontinuities. Perhaps one of the most familiar instances of this phenomenon is in glass cutting where a scratch (which is a small notch in cross section) produces a fracture with very little effort. In this case, stress concentration is utilized in an advantageous way to facilitate an operation. The trouble is that a notch produces the same effect when any stress reaches it and does not discriminate between desirable and undesirable stress concentration.

Under repeated loading, there sometimes occurs a type of failure known as "fatigue failure" which is the result of the propagation of a crack that originated at the base of some notch or sharp corner. The sharper the notch, the more severe is the stress concentration. Many such failures may be traced to tool marks on machined surfaces, lack of sufficient rounding in fillets and often to injury to the surface from hammer or chisel indentations.

The removal of the collar on axles in the new A.A.R. design eliminated a stress raiser at a point in the axle where the maximum stress was repeated with every revolution. Locomotive men are familiar with the care bestowed on the surface of driving rods so that no notch or dent shall become the focal point for the start of a fatigue crack.

Designing structures for high-strength steel presents no special difficulty. Engineering principles are established and unchanging, but certain features of design assume greater importance with high-strength steel. We have just seen that the thickness of material is reduced about 25 to 30%, and for flat surfaces this may call for special attention to the matter of buckling stability, which can be readily provided by proper design. The best and most economical utilization of high-strength steel is only attained by study and careful consideration of every detail of the structure.

The economic limit is the feature of most interest to railroads. A lucrative return can be obtained by the use of low-alloy, high-strength steels. Other materials, presumably, may go further in the matter of weight reduction, but at a penalty of severely increased cost. Calculations have indicated that this penalty runs from $1500 to $2000 per car, as compared to high-strength steel.

Light-weight construction is in the spirit of the times and merits a forward-looking approach to its possibilities.

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Construction of 100 All-Welded Cabooses Signifies Trend to Shielded Arc Methods

By A. T. Cox, Jr.*

THE construction of 100 all-welded caboose cars being built by Erie Railroad Co. at their Dunmore Shops, Dunmore, Pa., is indicative of the fast-growing preference toward arc-welded type of fabrication throughout the railroad industry.

The welded caboose as shown in Fig. 1 marks a new high in efficiency of design, as not only has this type of construction reduced the weight per car by 8900 lb., but it also eliminated the extra expense involved in punching, drilling and riveting that was necessary in the former design as shown in Fig. 2. In addition, the welded cars present a smooth, unobstructed surface that permits easier painting of the finished job and makes for better appearance.

According to welding authorities of The Lincoln Electric Railway Sales Co., Cleveland, Ohio, who provided engineering and supervisory service, the fabrication

* Vice-President, The Lincoln Electric Railway Sales Co., Cleveland 13, Ohio.

Fig. 1—Steel Caboose of Arc-Welded Design, One of 100 Such Units Being Constructed by the Erie Railroad Company

Fig. 2—Caboose of Former Riveted Design

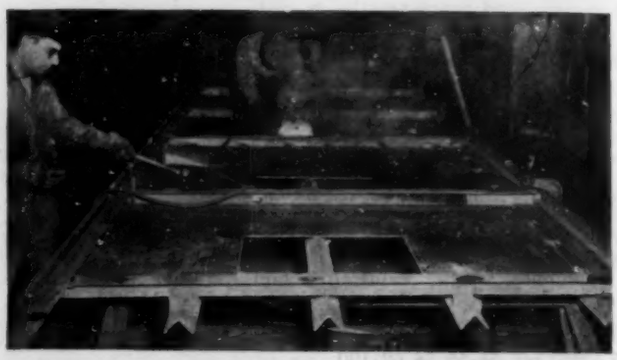

Fig. 3—Fabricating Side Section of Caboose by Shielded Arc Process

Fig. 4—Assembling Top and Cupola Prior to Finish Welding

Fig. 5—Applying Butt Welds to Assembled Unit

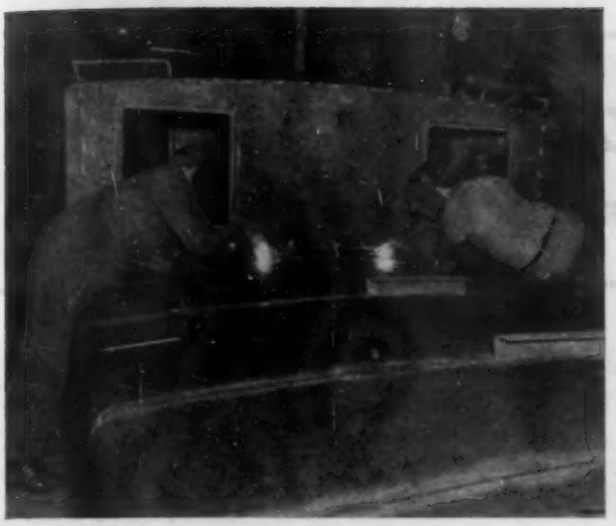

Fig. 6—Joining Cupola to Roof Member

Fig. 7—Welder Puts the Finishing Touches to Rear of All-Welded Caboose

of these structures offers an outstanding example of the progressive line system of production.

The sides and ends of the cabooses, of $^1/_8$-in. sheet steel, are assembled and clamped to a jig and butt welded to Z-bar posts. The members are first joined by tack welding (Fig. 3), then finish welded with a continuous bead using $^5/_{32}$-in. mild steel, shielded arc electrode of A.W.S. Specifications E-6012 and E-6013.

Details of the roof frame design are seen in Fig. 4 where workmen are positioning the pre-welded front section of the cupola to the roof. The sides, roof and completed cupola are then lifted into place on the caboose trucks by means of overhead cranes, and the finish welds are applied (Figs. 5, 6 and 7) to form a rigid single structure.

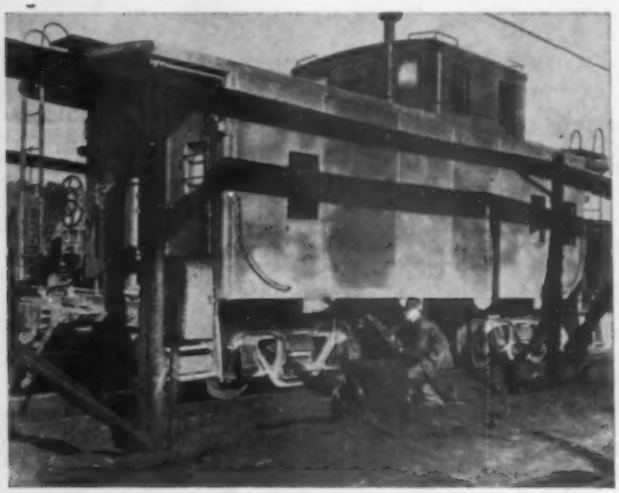

Fig. 8—Completely Welded Caboose Receiving Cement Coating on Underframe to Protect Against Corrosion and Rust

Completed cabooses are then rolled to a specially equipped outside rack where the exterior is thoroughly sand blasted to remove mill scale and rust.

After applying a corrosion-resistant coating of car cement to the underframe and roof top (Fig. 8) with a pressure gun, the cabooses proceed to the paint shop where the paint is applied by spray gun and brush methods.

The new cabooses have many new features derived from the ideas and suggestions made by the railroaders who use them as well as those who build them. The arrangement of the interior, for example, allows for larger bunks and greater floor space.

The all-welded cabooses are not only stronger, lighter and better appearing than the former riveted design, but are said to be much more economical from the standpoint of fabrication and maintenance.

(*Continued from page 649*)

Soldering. Soft-Soldering Non-Ferrous Metals. Oxy-Acetylene Tips, vol. 25, no. 2 (Apr. 1946), pp. 44–47.

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Tractors, Agricultural. Welding Shops Help Put Farms on Rubber. Oxy-Acetylene Tips, vol. 25, no. 2 (Apr. 1946), pp. 55–56.

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THE AMERICAN WELDING SOCIETY

ACTIVITIES – RELATED EVENTS

IRON AND STEEL EXPOSITION

The Iron and Steel Exposition, sponsored by the Association of Iron and Steel Engineers, will be held in the Cleveland Public Auditorium, Cleveland, Ohio, on October 1, 2, 3 and 4, 1946. The exposition, which is held in conjunction with the annual convention of the AISE, will feature exhibits of over 150 manufacturers supplying equipment and services to the nation's iron and steel, metal working and allied industries. The arena and exhibit hall of the Cleveland Auditorium will be utilized for the housing of the exhibits. An attendance of over 12,000 engineering, operating and supervisory personnel from the iron and steel, metal working and allied industries is anticipated.

Technical papers on various phases of plant operation and practice will feature the annual convention. These papers will be prepared and presented by authorities on engineering and operation from both metal-producing firms and the equipment-supplying firms.

NATIONAL WELDING SUPPLY ASSOCIATION

Welding equipment and supply distributors attending the second annual convention of the National Welding Supply Association at Dayton, Ohio, April 29th and 30th, elected L. O. Schneiderwind, Omaha, Nebr., President; Ralph E. Chase, Benton, Ill., senior Vice-President; and H. G. Weiler, Dayton, Ohio, Secretary-Treasurer. Ten trustees for one- and three-year terms were also elected.

Departing from a heretofore strictly distributor organization, NWSA members from every section of the country approved changes in their Constitution to make manufacturers of welding equipment, supplies and/or gases eligible for membership. Also of interest to the industry as a whole was a resolution adopted to the effect that NWSA will not foster or encourage cooperative purchasing or selling. A number of new active memberships were accepted at the convention to bolster a national membership that already extends from coast-to-coast.

NWSA is the only national trade association of its kind operating in the interest of the welding industry. Objects of the association are to promote and maintain such constructive cooperation among welding equipment and supply distributors and their sources of supply as will advance their mutual interests; inspire the observance of high business standards; stimulate the adoption of such business methods as will make for efficient and profitable operation; encourage adherence to sound policies and practices; correct faulty procedure and eliminate commercial evils; all to the end that the welding supply distributors may retain their place and identity as an essential and efficient service in the distribution of welding equipment, supplies and gases.

Manufacturers and distributors of welding equipment, supplies and gases are invited to write the National Welding Supply Association, Dayton 2, Ohio, for further information.

AMERICAN SOCIETY FOR BODY ENGINEERS

Announcement has been made of the formation of a new engineering society called The American Society of Body Engineers, Inc., by its president, I. Louis Carron, body engineer of the Detroit Harvester Co. The society has been organized as a nonprofit corporation with national headquarters in the Rackham Memorial Bldg. in Detroit, Mich. This is an aggressive organization composed entirely of leading body engineers from practically all the companies in the automotive industry.

Mr. Carron states that the forerunner of the present-day body engineer was a carriage maker, an artisan who at the turn of the century was capable of designing and building his own carriages. He had to be an artist as well as a first class wood worker and upholsterer. It was natural for men of these talents to turn to the building of bodies for the new contraptions then called "horseless carriages." Very few of these men were college-trained engineers, and any knowledge of engineering was acquired through practical experience. Today a successful body engineer must be well versed in the fundamentals of engineering and in addition, must be a good artist. There is no part of an automotive vehicle as important as its body with its flowing lines and pleasing contours which needs the touch of the artist in its design, as well as the use of the fundamentals in engineering for the proper selection of materials for its construction.

Recognition of the fact that Body Engineering has reached the status of a profession is seen in the recent announcement of the University of Michigan that this fall it will start a course in Body Engineering which will lead to the granting of a degree in Engineering.

A Technical Convention will be held in October by this society, The American Society of Body Engineers, Inc., in the Rackham Memorial Bldg. with Carl W. Cenzer as General Chairman. Elaborate plans are already well underway. Committees are being formed and are to be headed by capable and experienced men who have devoted many years toward the progress of body design and engineering.

BRITISH WELDING STATISTICS
(Furnished by BEAMA)

Arc Welding Electrodes

The 14 firms making electrodes have increased their labor force since 1938 as follows:

	1938	1945
Male	370	780
Female	1070	1590
Total	1440	2370

i.e., an increase of 65%.

The output of the industry in 1944 was four times the 1938 output, and output at the end of 1945 is three times the 1938 figure. Actual figures are:

1938	1944	1945
£1,060,320	£4,247,460	£3,103,300
385,571,000 ft.	1,415,821,000 ft.	1,034,428,000 ft.
11,720 tons*	45,020 tons	34,200 tons

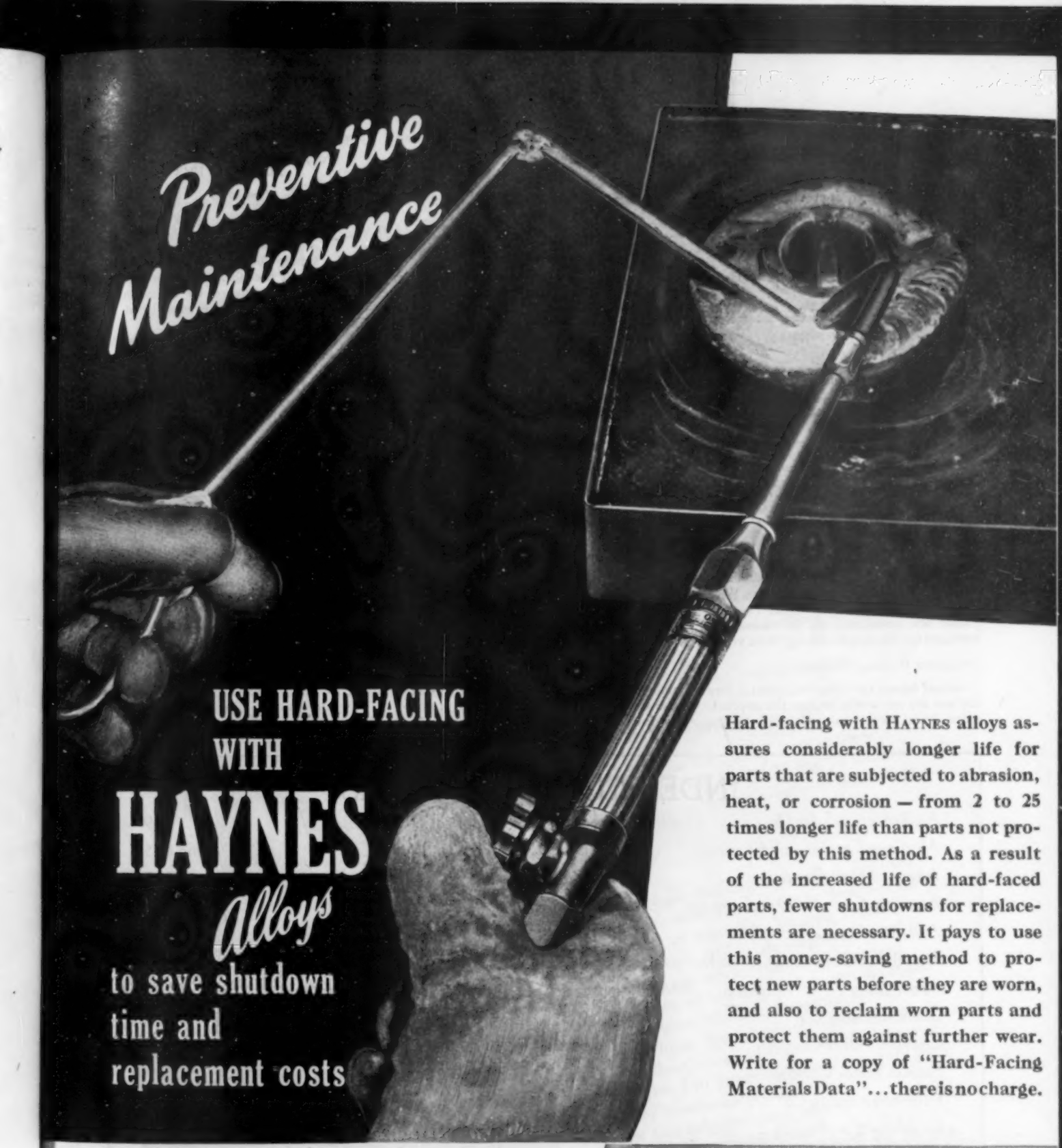
* Long ton = 2240 lb.

Twenty-five per cent of the 1945 total sales are for export as compared with 18% in 1938.

As a result of the increased use of arc welding and the experience gained during the war years, it is anticipated that the demand for electrodes will not fall below about three times the 1938 figure, and that, as further applications for arc welding are developed, the demand for electrodes will increase. There is ample manufacturing capacity for all anticipated requirements.

Arc Welding Plant

Employment figures for this industry are difficult to assess because some of the



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manufacturers also make other types of electrical equipment, and labor is not allocated full time to the manufacture of welding plant. However, it has been ascertained that an approximation of the labor force employed is about one worker to each 10 machines produced per annum (i.e., about 250 in 1938 and 800 in 1945) and approximately 75% is female and 25% male. The output of the industry (Home and Export) is shown below:

	1938	1944	1945
Number of arc-welding plants installed	2,750	12,100	8,800
Value	£187,000	£903,100	£740,000

The total number of arc-welding plants installed in the country is estimated at:

1938	1944	1945
20,000	60,000	65,000

The statistics available for Home Sales of Electrodes give an indication that the average quantity of electrodes used on one machine each year is approximately, 1938, 9 cwts.; 1944, 14 cwts.; 1945, 11 cwts. Those are considered to be reasonable averages for the output during those years.

Resistance Welding Statistics

Actual figures for labor employed before the war are not available, but the approximate labor force now employed in the industry is given below. The figures are estimated, because several manufacturers also make other electrical equipment and have not assessed the labor actually employed in making welding machines:

1945 Labor Employed

No. of Firms	Male	Female	Total
14	584	166	750

As can be seen from the figures given below, the demand for resistance welding machines is greater in 1945 than in 1944, and it is anticipated that, as the industry is able to speed conversion to normal production, still heavier demands will be made upon the manufacturers.

The annual output of the industry has increased more than three times as is shown by the following figures:

Annual Output of Resistance Welding Machines

	1939	1944	1945
No. of machines	....	2,300	2,400
Total kva.	....	64,000	78,000
Value	£192,000	£612,000	£650,000

During 1943, particularly heavy demands were made upon the industry because of the increase in armament production which was planned during that year.

Output of Resistance Welding Machines, 1943

No. of machines	2,760
Total kva.	101,000
Value	£861,000

The steady increase in output during the war, and the phenomenal production in 1943, were achieved by the same 14 manufacturers who were established before the war.

The total number of resistance welding machines in operation in 1939 is estimated at 8000. The total number of machines installed throughout the country at the present time is estimated at 21,500 with a total kva. of about 860,000.

LT. COMDR. HUESTER COMPLETES IMPORTANT MISSION

The Army Air Forces Tropical Science Mission, of which Lt. Comdr. H. J. Huester, U. S. Navy Bureau of Aeronautics Technical Representative was a member, returned to Wright Field after flying 60,000 miles around the Equator and Pacific Area in a C-54 Douglas Skymaster. The mission was overseas four months to study the prevalent causes of deterioration to Air Forces, Quartermaster and Signal Corps equipment in tropical regions.

Lt. Comdr. Huester is a member of the Dayton Section of the AMERICAN WELDING SOCIETY.

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AIEE WELDING SESSION

The tentative program for the Summer Convention held in Detroit during the week of June 24th follows:

Monday Morning, June 24—Session on Resistance Welding

1. "Characteristics of Resistance Welding Transformers," by F. E. Murray and R. C. Jones, Taylor-Winfield Corp.
2. "Influence of Magnetic Materials on the Welding Characteristics of Resistance Welding Machines," by C. E. Smith and J. J. Riley, Taylor-Winfield Corp.
3. "The Application of Series Capacitors to Flash Welders," by James E. Deffenbaugh, Federal Machine & Welder Co.
4. "Voltage Changes Due to Resistance Welding Loads," by C. M. Rhoades, Jr., and H. A. Peterson, General Electric Co.

Wednesday Afternoon, June 26—Session on Arc Welding

1. "Power Requirements for D.-C. Arc Welders," by R. F. Wyer and R. C. Freeman, General Electric Co.
2. "Application of Limited Input Arc Welders to the Power Distribution System," by C. N. Clark, Duquesne Light Co.
3. "Limited Input Arc Welders," by E. Steinart, Westinghouse Electric Corp.

STABILIZED STEEL FOR HIGH TEMPERATURES

All patent rights to the use of a "stabilized" steel composition designed to meet requirements of increasingly high temperatures in the steam lines of power plants and in the chemical industry have been dedicated to public use by United States Steel Corp. of Delaware and Carnegie-Illinois Steel Corp. The use of the material, which has emerged from the Research Laboratory and subsidiary companies of United States Steel since the end of the war, was patented by Dr. Marcus A. Grossmann, director of research, and Dr. R. F. Miller, development engineer, stainless and alloy steels, of Carnegie-Illinois.

The patent was issued recently to Drs. Grossmann and Miller and relates to "the use of a grade of steel particularly resistant to graphitization when subjected to stress in the temperature range from 800 to 1100° F." According to the patent, the steel developed and specified for this service is a carbon-molybdenum-chromium composition.

"The studies and investigations underlying this development," says a statement by R. E. Zimmerman, Vice-President, Research & Technology, United States Steel Corp. of Delaware, "involved the extensive cooperative efforts of the Corporation's Research Laboratory at Kearny, N. J., and the research organizations of Carnegie-Illinois Steel Corp. and National Tube Co. In view of the importance of the invention to the power generating industry and the practical value of the teachings of the patent to many others, all rights under it have been proclaimed available to the public for use on a royalty-free basis."

Operations involving ever higher temperatures have focused the attention of metallurgists and engineers on specific compositions best suited to give industrial equipment long life and more efficient performance. Oil refineries, chemical process plants and steam power generating plants are typical examples of industries concerned with the use of steel at high temperatures.

"Formerly plain carbon-molybdenum steel was considered completely safe for use in stress at temperatures up to about 1100° F. since it was known to have adequate creep strength within this range," according to the wording of United States patent No. 2,359,043, which describes the composition of the steel. Recently, however, it has been found that with prolonged use at elevated temperatures the carbon in the steel graphitizes so as to produce planes of weakness .... It is believed that this effect might prevail at temperatures as low as 850° F. with adequate time, and it has been found definitely present at temperatures above 900° F."

At first, where conditions required a change from plain carbon-molybdenum steel it was common to use a more expensive material containing 1% or more of chromium, but it was found that chromium in such quantities considerably increased the cost of the steel and detracted somewhat from its creep strength. The use of the small amount of chromium in the Grossmann-Miller invention involves a

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The chart below gives maximum capacities on clean, mild steel under the various KVA and throat depth conditions. Minimum weldable gauge is 28. (U. S. Standard)

Transformer Rating	Throat Depth 12"	18"	24"	30"	36"
20 KVA	16 Gauge	18 Gauge	19 Gauge	22 Gauge	Not Supplied
30 KVA	14 Gauge	16 Gauge	18 Gauge	19 Gauge	22 Gauge
40 KVA	13 Gauge	14 Gauge	16 Gauge	18 Gauge	19 Gauge
50 KVA	12 Gauge	13 Gauge	14 Gauge	16 Gauge	18 Gauge
75 KVA	11 Gauge	12 Gauge	13 Gauge	14 Gauge	16 Gauge

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steel which is both practical and economical since the small additional cost is offset by greater service life. Further advantages are that the amount of chromium used does not materially affect creep strength, which remains approximately the same as that of the conventional carbon-molybdenum type, or may even provide improved creep strength. Since the small amount of chromium does not make the steel air-hardening, it can be handled and processed in the usual manner.

The steel embraced in the patent now made available to public use is of the pearlitic, nonair-hardening type containing from 0.08 to 0.20% carbon and from 0.45 to 0.65% molybdenum in conjunction with from 0.15 to less than 1 % chromium, which is proportioned with respect to the carbon content to fix substantially all the carbon in the form of carbide, which is stable within the defined temperature range, Dr. Grossmann said in describing the material. He added that this steel is not only more stable from the standpoint of graphitization and spheroidization but also has a strength equivalent to that of the carbon-molybdenum steel previously used.

FLAME-HARDENING CATALOG

Air Reduction Sales Co., New York 17, has published a new catalog describing design and use of Airco flame-hardening apparatus. Items covered in the catalog vary from simple water-cooled torches and tips for hardening small parts to complete apparatus for use on large jobs.

Since all Airco flame-hardening apparatus is light in weight and fully portable, it is possible to bring the heat to the work, with the result large parts may often be treated without removal from the assembly.

Airco catalog No. 90 includes equipment for gear hardening and hardening of both internal and external rounds, as well as flat surface hardening, and lists a variety of manifold, regulators, valves and seals.

THE METALLURGY OF STEEL CASTINGS

By Charles Willers Briggs, Technical and Research Director, Steel Founders' Society of America. 625 pages, $6^1/_2 \times 9^1/_2$, 334 illustrations, $6.50.

This authoritative reference work provides in a single volume a complete summary of present-day methods of technical and industrial control in the production of steel castings. It describes in complete detail every process used today in the manufacture of high-quality steel castings from basic open-hearth, basic-electric, acid open-hearth, acid-converter and acid-electric steel, and related factors, based on a survey of steel-casting practices of the past 15 years. Over 300 illustrations are given, including numerous photomicrographs of various steels before, during and after casting, together with many tables and charts of steel analysis. McGraw-Hill Book Co., Inc., 330 W. 42nd St., New York 18, N. Y.

TOUR & CO. EXPANDS

Sam Tour & Co., Inc., announce that on Oct. 1, 1945, a Department of Mechanical Engineering was added to the Chemical Engineering, Metal Finishing, Metallurgical Engineering and Physical Metallurgy facilities.

E. V. Crane, former Consultant and Chief of Development Engineering to E. W. Bliss Co.; author of some eighty technical and scientific papers on a wide variety of Engineering matters, as well *Plastic Working (of Metals and Non-Metallic Materials) in Presses* (a standard text here and abroad) is heading up the new department. Mr. Crane is assisted by competent mechanical engineers, designers and draftsmen.

This Department handles advisory service and engineering problems in the design of tools, dies, presses, special equipment, plant expansions and rearrangements, pilot plants and complete plants for the mass production industries.

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RegO offers a complete line of standard manifolds—wall-mounted and cross-type models in a range of sizes up to the largest for supplying complete pipe systems . . . and, in addition, there's a series of portable styles which provide manifold advantages at low cost and which fully meet the requirements for general use in the field.
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THE INTERNATIONAL NICKEL COMPANY, INC., 67 Wall St., New York 5, N. Y.

SAVES TIME AND LABOR ON PRODUCTION LINES

The National Rubber Machinery Company formerly mounted this switch box on steel supporting bars bolted to the cast iron base of the stock turret. The procedure required: (1) Chipping the casting face...at 4 places...until it conformed to the proper angle for fitting the bars against it. (2) Making a bracket. (3) Drilling and tapping bolt holes in the casting. Ni-Rod eliminated these operations...and made the application rapid, simple, easy.

Ordinary straight bars, held against the casting at the proper angle, are now welded on without further ado...saving considerable time and money. Moreover, by using Ni-Rod to build up the casting surface at spots where a top bar is to be welded, the manufacturer is able to square up both bars.

Welding procedure is simplicity itself. There is no preparation of the casting, nor is any pre-heating used. Welds are made in a single pass, using 5-32" Ni-Rod electrodes, and are peened with a hand hammer.

The welding operator on this job calls Ni-Rod, "the smoothest-running rod I ever used—easy to handle, and gives excellent fusion."

NI-ROD IS DISTRIBUTED BY:

WHITEHEAD METAL PRODUCTS COMPANY, INC.
Baltimore-Boston-Buffalo-Newark-New York
Philadelphia-Syracuse

WILLIAMS and COMPANY, INC.
Cincinnati-Cleveland-Columbus-Pittsburgh

STEEL SALES CORPORATION
Chicago-Detroit-Milwaukee-Minneapolis-St. Louis

PACIFIC METALS COMPANY, LTD.
Los Angeles-San Francisco

J. M. TULL METAL & SUPPLY CO.
Atlanta

METAL GOODS CORPORATION
Dallas-Houston-New Orleans-Tulsa

EAGLE METALS COMPANY
Portland-Seattle-Spokane

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ROBERT W. BARTRAM
Montreal

ALLOY METAL SALES, LTD.
Toronto

WILKINSON COMPANY, LTD.
Vancouver

Call or write for more information

New York Section Inspection Group at the Plant of the Metal & Thermit Corp., April 27, 1946

NEW YORK SECTION INSPECTION TRIP

Members and guests of the AMERICAN WELDING SOCIETY's New York Section turned out almost 200 strong for an inspection trip to the Metal & Thermit Corp.'s Research Lab. at Woodbridge, N. J., on Saturday, April 27th.

Providing one of the first opportunities offered since the War to visit an industrial research laboratory and to see at first hand some of the wartime and early postwar developments in arc welding and Thermit welding, the day proved both interesting and informative to those who made the trip.

The program included the showing of a new motion picture, "Mass Production of Massive Parts," followed by guided tours, in groups of ten or so, through the analytical, chemical and pilot plant divisions of the laboratory with demonstrations of equipment and procedures at various points in the welding division. Of particular interest to those who attended were the demonstrations of welding and cutting of steel under water and the Thermit reactions which were shown in connection with the welding of rail and the production of steel castings.

John B. Tinnon, Vice-President, and Dr. Lincoln T. Work, Director of Research of the Metal and Thermit Corp., officiated. Charles Kandel of the Craftsweld Equipment Co., headed the AMERICAN WELDING SOCIETY committee on arrangements. Specialists who explained the various demonstrations and who were available to answer questions were: H. O. Klinke (Stainless Steel Welding), Air Reduction Sales Co.; E. Vom Steeg (Mild Steel Welding, All Position), General Electric Co.; Lysle Wilson (Mild Steel Welding, Downhand), American Bureau of Shipping; R. C. Pearson (Tensile and Navy Bend Tests), Brooklyn Navy Yard; H. R. Isenburger (X-ray Inspection), St. Johns X-ray Labs.; C. D. Cooper (Underwater Welding and Cutting), Metal & Thermit Corp.; J. H. Deppeler (Thermit Welding), Metal & Thermit Corp.

TUBE TURN APPOINTMENTS

C. C. McDermond has been appointed representative of the welding fittings division of Tube Turns, Inc., in Venezuela and Colombia, S. A., it is announced by Jack Green, the firm's sales manager. McDermond and his assistant, C. T. McCoy, make their headquarters in Apartado No. 331, Maracaibo, Venezuela.

McDermond has long been prominent in the petroleum industry, in both North America and South America. He began his highly successful career in 1914 with The Texas Co., as sales representative in Western Florida. After World War I, he was assigned to the company's West Tulsa refinery, where he began acquiring his present broad knowledge of petroleum processes and products. Later he was made manager of sales in Tulsa, then was transferred to Tampico, Mexico, where he held numerous posts in the field. During the peak production period in Mexico, he was the chief scout for The Texas Co.,

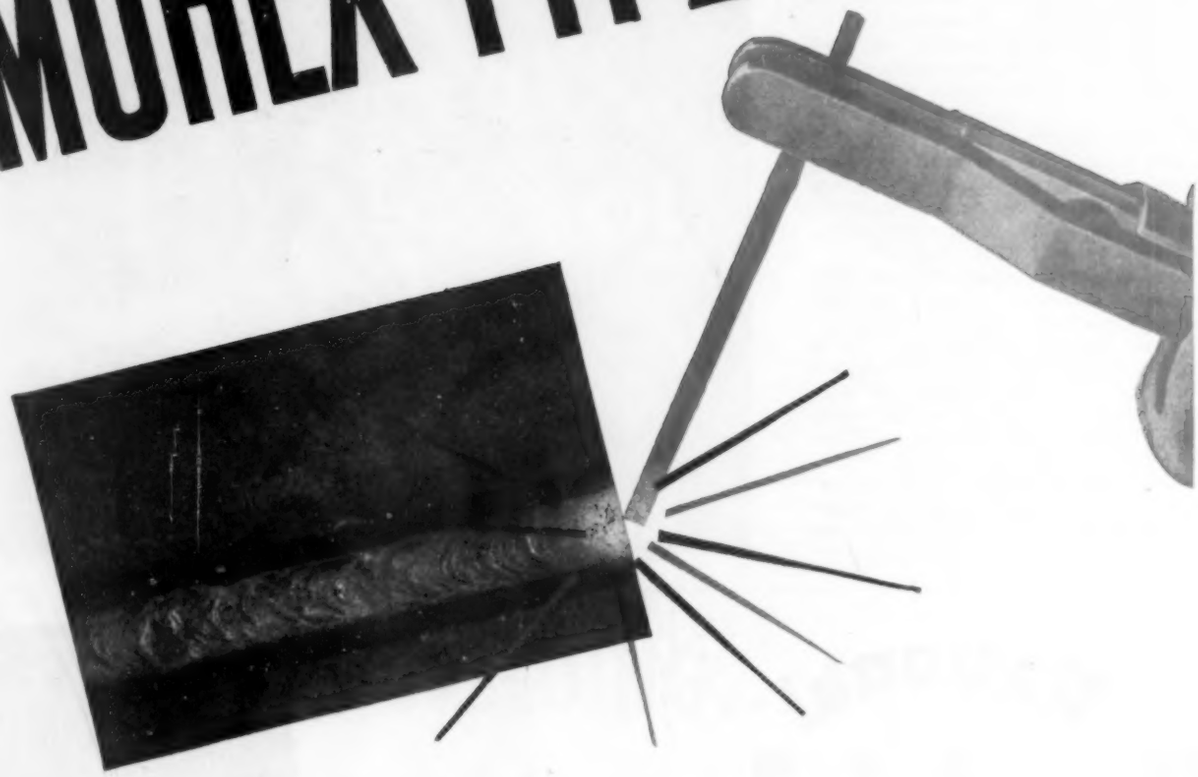
C. C. McDermond

covering all territory south of Tampico to the Tuxpam River. In the latter part of 1923, he was placed in charge of wildcatting operations in the Republic of Panama, and while there he supervised the drilling of a deep test in the Province of Chirique. In 1925, he went to Venezuela as representative of the Creole Syndicate, whose holdings were then being developed by the Venezuelan Gulf Oil Co. By 1928, when he resigned to enter business for himself, 150 producing wells had been brought in for the syndicate.

McDermond's first venture on his own was a scouting service, which he continues to operate. In addition, he founded the Compania Cartografica, a map-making firm, and assisted in establishing and managing Pan American Airways' operations in Western Venezuela. He has since expanded his business interests to the representation of many well-known American manufacturers.

C. T. McCoy

MUREX TYPE HTS



The Right Electrode for Hard-to-Weld Steels

Developed primarily to prevent underbead cracking when welding high tensile steels without preheating, Murex Type HTS is an all-position rod providing weld metal of 70,000 psi tensile strength with ductility and X-ray soundness equal to that of welds made with downhand electrodes.

Because of its moderate penetration and low pick-up of undesirable elements from the parent metal, it is particularly useful in welding high-carbon, high-sulphur and other difficult-to-weld steels.

The complete facilities of our welding laboratory are available to help users of Murex electrodes achieve superior welds at lower costs. More detailed information on Type HTS or other widely-used Murex rods is available on request.

METAL & THERMIT CORPORATION

120 Broadway, New York 5, N. Y.

Albany • Chicago • Pittsburgh • So. San Francisco • Toronto

MUREX ELECTRODES

McCoy, McDermond's assistant and field engineer, also is widely known in the petroleum industry, with which he has been identified for 22 years. He is regarded as a top specialist in the various applications of oil well equipment and is the designer of oil well devices and equipment.

"AMPCO WELDING NEWS"

"Ampco Welding News," a publication issued by the Weldrod Sales Dept. of Ampco Metal, Inc., Milwaukee 4, Wis., is distributed free to welding engineers, practical welders and production men who are interested in the latest methods of using aluminum bronze and phosphor bronze welding electrodes.

This 8-page letter-size quarterly magazine is profusely illustrated with application scenes, diagrams, tables and fact stories relating to welding with Ampco-Trode and Phos-Trode electrodes.

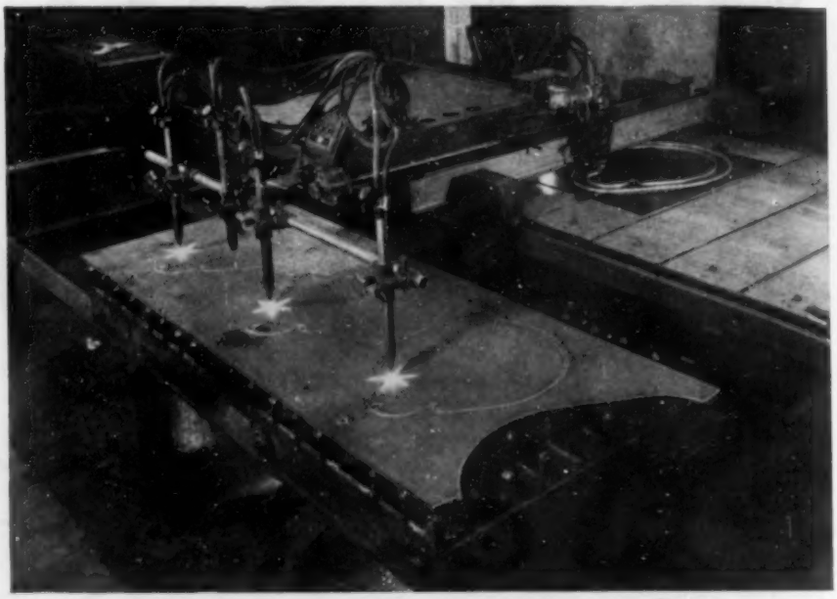
Ampco-Trode is a high-strength, high-hardness, aluminum bronze electrode, having remarkable wear resistance and excellent bearing characteristics. It is made in 5 grades with a range of physical properties. Used for building up worn shafts, wear strips, valve seats, overlaying bearing surfaces and refacing steel and cast iron for added wear resistance.

Phos-Trode is a shielded-arc, heavy-coated d.-c. phosphor bronze electrode. Phos-Trode is easy to manipulate in all poistions. The arc is soft, resulting in a transfer of metal in a spraying action. It is suitable for welding bronze, brasses, copper, steel and cast and malleable iron.

Copies of recent issues will be sent free on request.

MULTIPLE SHAPE CUTTING

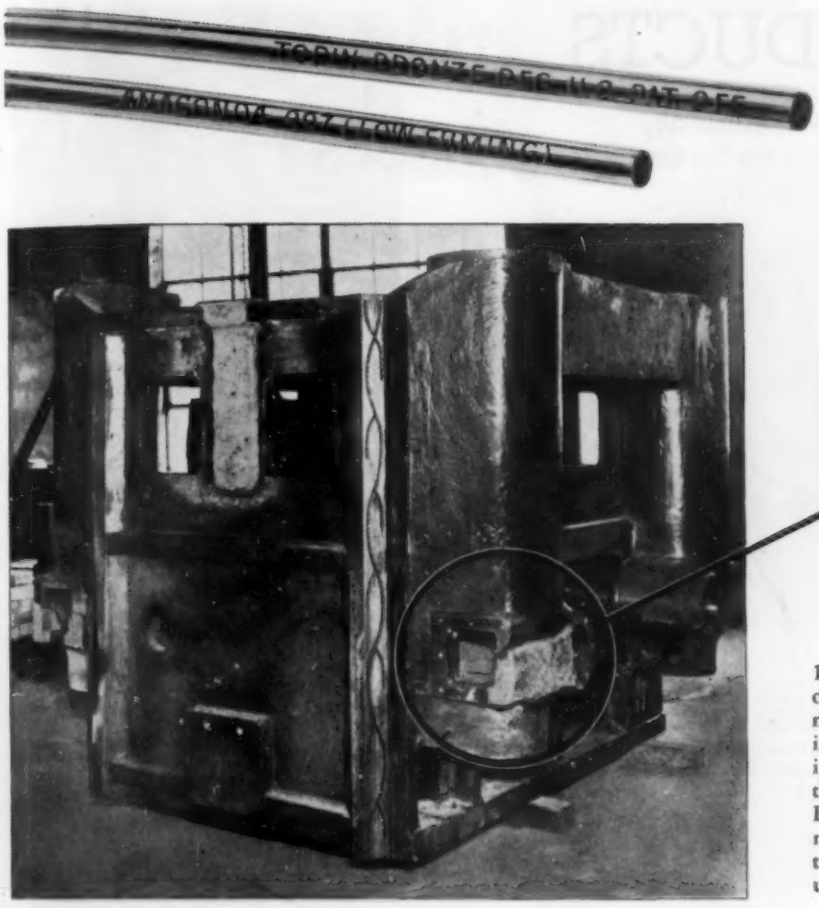
Large numbers of similar shapes can be accurately cut from steel plate material, using a multiple-blowpipe setup such as that shown here. Three gear-case covers are being cut simultaneously with this Oxweld CM-12 machine from $^{5}/_{8}$-in. steel plate. Irregular shapes can be cut repeatedly with the same accuracy by using a templet guide for the machine. The aluminum strip templet can be seen at the right between the cutting-machine carriage rails.



National
Carbide
IN THE RED DRUM

EFFICIENT
ECONOMICAL
DEPENDABLE

FOR WELDING and CUTTING
Use National Carbide in the Red Drum
Write us for information as to nearest available stock.
60 E. 42nd St. NATIONAL CARBIDE CORPORATION New York 17, N. Y.



18,500-pound Hydraulic Press Casting • 350 pounds of Tobin Bronze saved this expensive piece of automobile production equipment. Two hydraulic cylinders were repaired as illustrated at the left, and in the close-up above. The casting was received by the Super Arc Welding Company of Detroit on a Friday, and delivered to the customer on Monday morning ready for machining. The Bronze weld in the frame, made several years ago, has stood up under heavy production ever since.

BRONZE WELDING...*First Aid for repairs on big jobs like this*

THE ILLUSTRATIONS above are typical of the equipment on which economical, permanent repairs can be made with Tobin* Bronze, "997" (Low Fuming) and other Anaconda Bronze Welding Rods.

For years this method of low-temperature repair welding has been used for reclaiming broken, fractured or worn equipment, or for building up bearing surfaces. Almost any part made of cast iron, steel, malleable iron or copper alloys can be Bronze welded quickly, dependably, and at a fraction of the cost of new replacement parts.

Publication B-13 will tell you more about Anaconda Welding Rods for oxy-acetylene repair and construction work, and electric welding of copper and copper base alloys. A copy of this booklet will be sent on request.

*Reg. U. S. Pat. Off. 46200

ANACONDA

Anaconda

WELDING RODS

THE AMERICAN BRASS COMPANY

General Offices: Waterbury 88, Connecticut

Subsidiary of Anaconda Copper Mining Company

In Canada: ANACONDA AMERICAN BRASS LTD., *New Toronto, Ont.*

NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this Section

ELECTRODE FOR WELDING "MONEL" METAL

Arcos Corp. announces an addition to its line of electrodes for welding nickel and nickel-copper alloys. Trade-named Monend, this electrode is used in welding wrought, cast or clad "Monel" (d.-c. reverse polarity). The Company also manufactures Nickelend electrodes for welding Nickel and Nicuend for welding cupronickel.

Complete details and samples are available on request from Arcos Corp., 310 Gulf Bldg., Philadelphia 2, Pa.

PORTABLE RAIL CROPPING MACHINE

A six-page, illustrated folder describes the new Air Reduction rail cropping machine. Operating instructions are included as well as repair and replacement parts lists for the rail cropping machine and the two torches with which it is equipped.

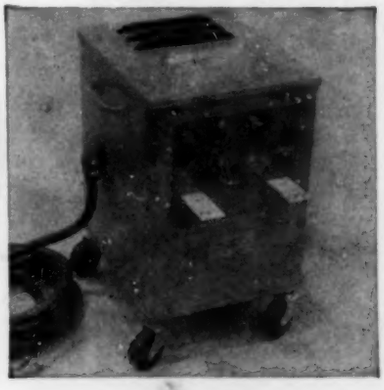
The folder explains how Airco's new machine simplifies the process of cropping relay rails. Air Reduction Sales Co., 60 E. 42d St., New York 17, N. Y.

10-KVA. PORTABLE BRAZER

For general brazing service in joining copper or copper alloy parts which may be brought together between the jaws of brazing tongs, a new portable 10-kva. brazer with air-cooled tongs is announced by the Westinghouse Electric Corp.

The new single-phase, 60-cycle unit weighs 100 lb., is provided with four large caster-type wheels and two convenient handles for quickly moving or carrying any place in the shop or yard. It requires only connection to a 220- or 440-v. source. Alternating current from an adjustable voltage transformer passes through the tongs and parts to be brazed.

The transformer with line contactor is enclosed in a sturdy sheet-metal case, and a clamp-type entrance bushing is provided for the incoming primary cable. Built into the front of the brazer, the control panel contains outlets for brazing tong cables, receptacle for foot switch pilot cable and voltage tap changing plug. The two-pronged plug-in switch quickly changes brazing voltage to 12, 10 or 8 v. A switch for energizing the contactor control circuit is also provided on the control panel. Cooling of the unit is effected by natural air draft which enters at the bottom passes over the brazing transformer and is expelled through louvered openings at the top.



Further information concerning the 10-kva. brazer may be secured from the Westinghouse Electric Corp., Box 868, Pittsburgh 30, Pa.

"MOBILE" TYPE SELF-PROPELLED ARC WELDER

The Hobart Brothers Company, Troy, Ohio, is announcing its latest models of "Mobile" Type Self-Propelled Arc Welders. Originated to simplify welding operations in the various yards of large railway companies, this unit is gaining popularity for maintenance welding operations around large oil refineries, steel mills, quarries, gravel pits and other extensive industrial plants where it is desirable to take the welding machine directly to the job.

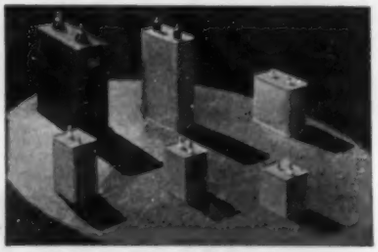
Welding equipment consist of a 300-amp. welding generator and tank carriers for oxyacetylene welding. The door to tool chest in rear becomes a convenient welding and work bench when opened. A Chrysler Industrial 6-cylinder engine furnishes power for welding and transportation. Special cable reel has capacity for 75 ft. of both electrode and ground cable and is optional equipment. Current supplied to the reel permits immediate welding at any desired cable length.

The unit has an automotive type transmission, three speeds forward and one reverse. It is connected directly to the welding generator. Fluid drive with rear mounted clutch permits smooth transmission of power, to a transfer case which may be equipped with one to one, or two to one gear ratio, depending upon the requirements of the unit. Clutch is dry disk type, 10 in. diameter. Brakes are four wheel hydraulic. A mechanical hand brake is on drive shaft. All controls are

automotive type and the unit is mounted on springs and shock absorbers in front and rear.

ENERGY STORAGE CAPACITORS

Development of a complete new line of small, lightweight, d.-c. Pyranol capacitors for use in flash-photography apparatus, light-metal welders and similar applications requiring economical energy storage, fast discharge and over-all reliability, has been announced by the General Electric Co.



Available in a wide range of ratings, with ambient temperature operating limits at rated voltage ranging from 0 to 50° C. and capacitance tolerances at 25° ±10% these units, meet practically every requirement of high-speed or stroboscopic photography as well as home and industrial welders.

CABLE SPLICERS

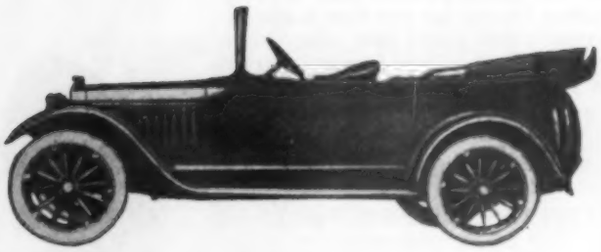
A complete new line of Welding Cable Splicers has just been announced by the TWECO Products Co., Wichita 1, Kan. The new product is a companion to the quick-detachable connectors already offered by the company.

TWECO Cable Splicers provide a quick repair of broken cables or salvaging short lengths. A simple clamp cable connection on each end of the splicer, with provision to solder between the cable ends, assures an efficient connection. A fiber sleeve covers this permanent, low-cost, easily installed cable splicer.

Made in three sizes to cover the full range of welding cables. Size "S" for small No. 4, 2 or 1 cables; size "M" for medium No. 1/0 or 2/0 cables; size "L" for large 3/0 and 4/0 cables. Full information will be furnished by writing the manufacturer.

1918 Motor Cars and 1946 Planes

WELDING MADE THEM POSSIBLE



1918 **Electric arc welding,** as a practical mass-production tool, was used for the first time in the building of automobiles in 1918—when A. O. Smith welded the rear axle housings for the 1919 Chalmers motor car.

1946

Today, A. O. Smith research developments make welding the modern production tool for all transportation —automotive, rail, ship, plane. Every B-29, for example, lands on SMITHway-welded landing gear.

THE PROOF IS IN PRODUCTION

America's tremendous industrial production—in peace and war—could not be achieved without the modern production tool, welding.

More than 7 million tons of steel products have been welded by A. O. Smith, whose plants have used as many as 320,000 SMITHway Electrodes *daily.* Millions more are used by fabricators and builders everywhere.

Each one is the proved result of A. O. Smith welding research, a search for improvement that never ends.

SMITHway A. C. Welders

A complete line of six models—150-, 200-, 250-ampere capacity; and for heavy-duty service, 300-, 400-, and 500-ampere capacity. Write for complete specifications and prices.

made by welders . . . for welders — *Mild Steel . . . High Tensile . . . Stainless Steel . . . Welding Electrodes*

SMITHway Certified WELDING ELECTRODES

A. O. SMITH Corporation

NEW YORK 17 • PHILADELPHIA 5 • PITTSBURGH 19
CLEVELAND 4 • ATLANTA 3 • CHICAGO 4 • TULSA 3 • MIDLAND 5 • DALLAS 1
HOUSTON 2 • NEW ORLEANS 16 • SEATTLE 1 • SAN FRANCISCO 4 • LOS ANGELES 14
INTERNATIONAL DIVISION: MILWAUKEE 1 • In Canada: JOHN INGLIS CO., LIMITED

TWEEZER SPOT WELDER

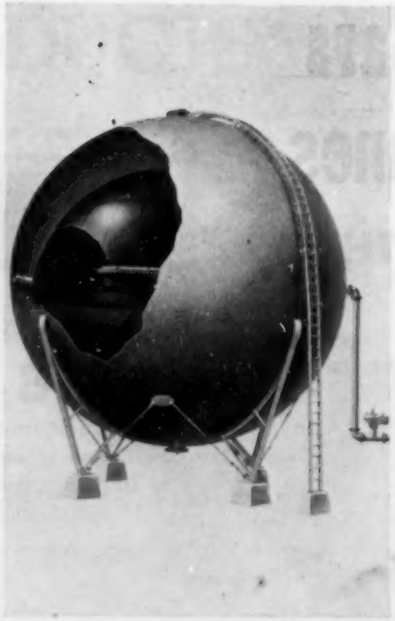
A new Besco Tweezer Spot Welding Machine Catalog has just been issued by Tweezer-Weld Corp., 280 Plane St., Newark 2, N. J. Those interested in this new development in spot welding may obtain a copy of the catalog.

FIRST VAPORSPHERE INSTALLED AT MOBILE, ALA.

The first Vaporsphere for reducing evaporation losses from flat-bottom tanks storing volatile liquids has been installed at the Hempstead Oil and Storage Co. at Mobile, Ala. This spherical structure, which prevents loss by providing temporary storage for vapor displaced by breathing, was designed by the Chicago Bridge & Iron Co., Chicago, Ill.

The Vaporsphere at the Hempstead Oil and Storage Co. has a capacity of 5000 cu. ft. and is connected to the vapor spaces of two flat-bottom tanks storing motor gasoline by 6 in. diameter light-weight vapor lines forming an effective vapor saving system. When increasing temperatures cause expansion in the tanks the excess vapor flows through the vapor lines into the Vaporsphere where it is stored temporarily. When conditions causing its displacement have changed, the vapor returns to the tanks.

Vaporspheres are also used to prevent filling losses from pressure tanks by designing them to operate at the same pressure as the tanks and equipping the air space with a pressure regulator.

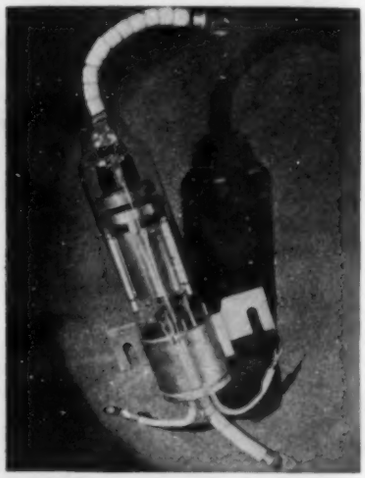


Cutaway View of a Vaporshere Showing the Flexible Membrane Connected to the Shell at the Equator

The Vaporsphere consists primarily of a spherical steel shell with a flexible hemispherical membrane on the inside. It is connected to the shell at the equator. Vapor is stored beneath the membrane and the space above is filled with air at all times. The Vaporsphere is supported by four structural cradles resting on individual concrete piers.

GRID CONTROL RECTIFIER TUBE

Electrons, Inc., 127 Sussex Ave., Newark 4, N. J., announce the development of a new Xenon Gas Filled Grid controlled (Thyratron) Rectifier tube type C16J. The tube is applicable to welding control, power rectifiers and vibration motors. It is ideal for smooth stepless electronic motor speed controls.



...is THIS your cleaning problem?

Conditioning Welded Steel Assemblies Before Painting

To secure good initial adhesion and permanent grippage of organic finishes on welded steel assemblies, use specialized Oakite surface-conditioning materials. These free-rinsing, quick-emulsifying compounds thoroughly prepare the physically clean surface required by paint or lacquer coats.

If you have a job in the shop which calls for particularly tough-to-meet finishing specifications, begin by checking your alkaline degreasing solution. Oakite installations are both efficient and economical! Used as directed, Oakite solutions last longer, clean better!

Your nearby Oakite Technical Service Representative will gladly help you select the Oakite metal cleaner that best fits your job! Call him TODAY, or write for FREE details.

OAKITE PRODUCTS, INC., 18E Thames St., NEW YORK 6, N. Y.

Technical Service Representatives Conveniently Located in All Principal Cities of the United States and Canada

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MATERIALS · METHODS · SERVICE · FOR EVERY CLEANING REQUIREMENT

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WELDERS

AIR, FOOT or MOTOR Operated Press Type Welders of All Sizes.

We manufacture a complete line of resistance spot welders from ¼ to 300 KVA for all types of welding. There is an EISLER WELDER for every purpose.

Transformers of all types.

We invite contract spot welding in large or small quantities.

Write for Catalog

EISLER ENGINEERING CO.

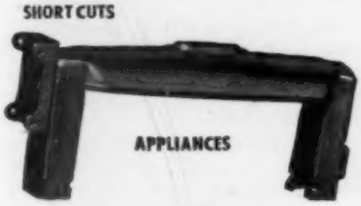
779 So. 13th St. (near Avon Ave.) Newark 3, N. J.

Auto Industry Has Many Examples of "Necessities Production" Sped by Federal RESISTANCE WELDERS

ACCESSORIES

RADIO PARTS

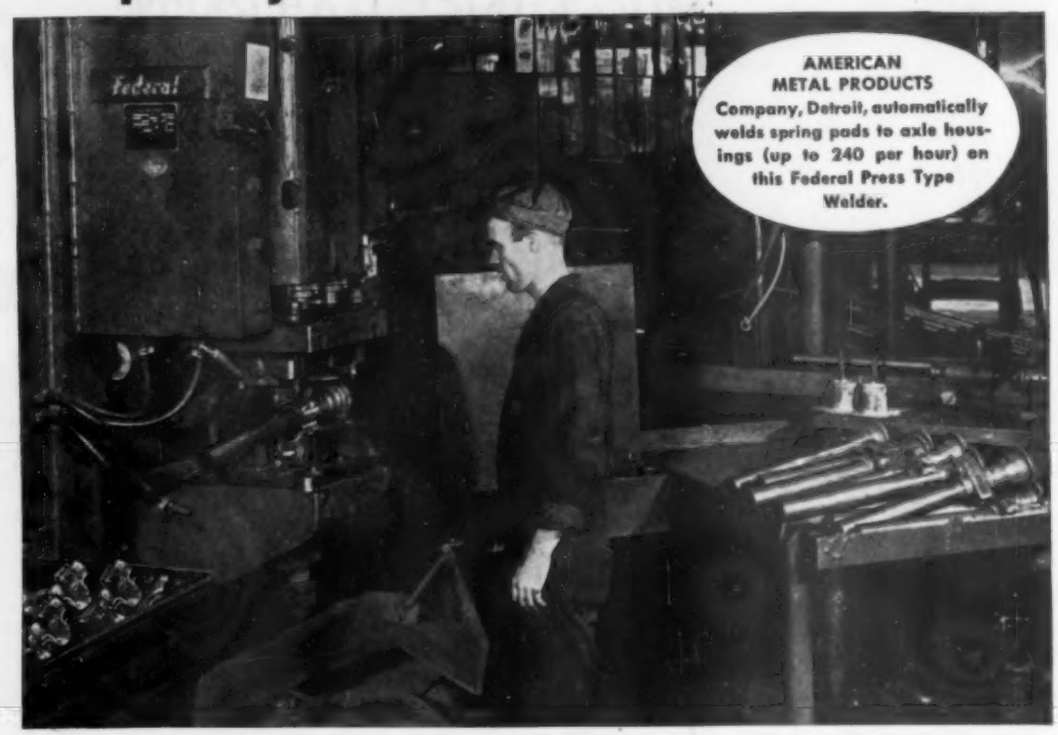
PRODUCTION SHORT CUTS



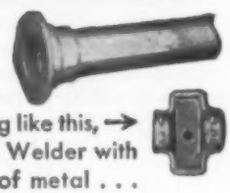
APPLIANCES

UTENSILS

PROJECTION WELDED — Thousands of variations of the typical items above are produced at low cost on Federal Welders described in Bulletin 4520.



AMERICAN METAL PRODUCTS Company, Detroit, automatically welds spring pads to axle housings (up to 240 per hour) on this Federal Press Type Welder.



For instance, you can take a heavy-gauge steel tube like this,→ which is a rear axle housing component, and a heavy gauge stamping like this, → which is a spring pad; insert them in a Federal PA-4 Press Type Welder with simple dies (shown left) and they come out as though one piece of metal . . . but stronger. Fifteen seconds total time. That's four pieces a minute.

Note the three nubs projecting inwardly on each side of the saddle portion of the stamping. At these points of contact between stamping and tube, welds initiate. Under heat and pressure the parts are forged together in these areas, the junctures becoming stronger than surrounding parent metal.

To the vast saving of time, against previous joining methods, add time savings on final assemblies and great economy in material resulting from this design. (Heavy castings were used where lighter but tougher stampings now do the job). There you find the reasons why industries noted for making the most of needed goods at the lowest cost are largest users of Federal Resistance Welders.

This is typical of hundreds of Federal welded jobs produced by the American Metal Products Company of Detroit, makers of quality parts for many industries. It is typical too, of thousands of other production-speeding, cost cutting methods possible with Federal Resistance Welders.

Every delay of full-scale production for the dammed-up needs of world markets through shortages of material or of work makes the need for eventual production speed more important . . . lowering of unit costs more urgent. When you find out (through the Federal Engineering Service nearest you) how you can cut cost and time in YOUR production with automatic welding, be sure that you get Resistance Welders by . . . Federal

BULLETIN SP 346 Describing Federal Spot, Flash, Projection, Seam and "Gun" Welders is yours for the asking.

THE Federal MACHINE AND WELDER CO.

SUBSIDIARIES
Sommer and Adams Co., Cleveland—SPECIAL HIGH PRECISION MACHINES
The Warren City Mfg. Co., Warren—WARCO PRESSES and PRESS BRAKES

MEMBER RWMA

ABSTRACTS OF CURRENT WELDING PATENTS

Prepared by V. L. Oldham

Printed copies of patents may be obtained for 10¢ from the Commissioner of Patents, Washington 25, D. C.

2,399,331—Arc Welding System; Clinton L. Denault, *Inventor;* Sharon, Pa.; assignor to Westinghouse Electric Corp. *5 Claims.*

This patent covers the coupling of a high-frequency generator to an arc welding circuit to supply a series of high-frequency pulses during a portion only of each half cycle of the a.-c. voltage applied to the generator. The high-frequency generator is supplied with a. c. in such phase relation to the arc welding circuit voltage that high-frequency impulses are produced principally between the time that the welding circuit voltage reaches an arc sustaining value and when it is a maximum.

2,399,356—Method of Welding Plates; Hans Klopstock, London, and Abram Rupert Neelands, Doncaster, England; *Inventors. 1 Claim.*

The edges of the plates welded by this process are chamferred and abutted to form a trough and a rod of welding metal is pressed into the trough and simultaneously rotated and fed along the trough. The pressure exerted is sufficient that the frictional heat developed raises the plates and the end of the rod to molten condition so that the rod and plate metals amalgamate and form a homogeneous bond, when cool.

2,399,377—Arc Welding System; William E. Pakala, Forest Hills, and Alfred B. White, Murrysville, Pa., *Inventors;* assignors to Westinghouse Electric Corp. *10 Claims.*

In this patent, a relatively high-frequency generator is coupled through means including an inductance coupling to a relatively low-frequency arc circuit. The inductance coupling determines the value of the high-frequency voltage applied to the arc circuit while control means are provided to shunt a portion of the inductance so that the high-frequency voltage can be reduced to and maintained at a lower operating value to assist in re-establishing the low-frequency arc circuit.

2,399,415—Arc Welding System; Alfred B. White, *Inventor;* Murrysville, Pa.; assignor to Westinghouse Electric Corp. *13 Claims.*

White's arc welding system comprises a welding transformer wherein the transformer's secondary is adapted to be connected to a welding electrode and work on which an arc weld is to be made, and inversely connected valve means that include circuit means that control the instant in each half cycle at which the transformer's primary is connected to a source of a. c. so as to provide heat control. Further circuit means having energy storage means therein are connected in shunt relation to the valve means so as to be charged during the nonconducting portion of each half cycle and coupled with the arc circuit independently of the welding transformer so as to discharge through the valve means and produce a single relatively steep wave front impulse between the work and the electrode each time the valve means is rendered conductive to connect the primary winding to its a.-c. source.

2,399,453—Electric Flash Welding; James McGregor Sinclair, *Inventor;* Inverness, Scotland; assignor of one-half to William Forbes Young. *4 Claims.*

The patented electric resistance welding machine includes a welding transformer having a multi-tapped primary winding, and first and second contactors adapted to connect a current supply to different taps of the transformer with the first contactor being used during the welding operation. Then means, responsive to movement of the welding head of the machine, are provided to open the first contactor and close the second at the completion of a welding operation. The machine also has means, responsive to the temperature of the welded article, for actuating the second contactor to interrupt and re-establish the circuit through the primary of the transformer.

2,399,646—Heated Backing-Up Strip for Sheet Metal Welding; Walter R. Linden, *Inventor;* Palisades Park, N. J.; assignor to The Linde Air Products Co. *8 Claims.*

Linden provides a backing member for preventing distortion of material being welded and it has a top portion conforming to the underside of the material being welded, and a central portion depending therefrom which increases in width toward its bottom. The backing member also has depending side flanges spaced from, and parallel to, the downwardly diverging sides of the central portion to prevent warping of the backing member. The space between the central portion and side flanges is unobstructed to leave a clear passage for heated gases.

2,399,771—Magnetic Arc Starter for Welding Machines; Joseph M. Turner, *Inventors;* New York, N. Y.; assignor to Air Reduction Co., Inc. *4 Claims.*

The patented starter has an electrode mounted in a holder attached to the underside of a crossbar, an armature bar attached to the upper side of a crossbar, a magnet, and a bracket, carried by the welding apparatus, for mounting the magnet. Guide means interconnect the ends of the crossbar and bracket to mount the armature opposite the pole of the magnet in limited movable relation thereto. The magnet includes a winding of large wire interconnected between a welding current source and the electrode so that the electrode is drawn up by the magnet after the welding current is turned on.

2,399,797—Spotweld Horn and Electrode Assembly; Bernard Gross and Leo W. Cornwall, *Inventors;* San Diego, Calif.; assignors to Rohr Aircraft Corp. *6 Claims.*

A longitudinally split spotweld horn with an electrode and an electrode holder mounted therein and extending therefrom is disclosed in the patent. The outer end of the horn and the electrode holder have connected passages therein for the circulation of water to and from the electrode, and removable inlet and outlet water tubes are housed within the horn and connect to the passages to form a circulatory system for cooling the electrode.

2,399,815—Method of Welding; Wesley G. Martin, *Inventor;* Milwaukee, Wis.; assignor to A. O. Smith Corp. *5 Claims.*

Martin's method is for use in welding together members at least one of which has a ceramic enamel coating. He stretches the uncooled weld in a direction opposite to its contraction, and supports the weld against contraction while it cools to reduce, substantially, the movement of the member due to the contraction of the weld.

2,399,979—Method for Improving the Operation of Oxygen Cutting Torches; Paul L. Betz, *Inventor;* Baltimore Md.; assignor to Consolidated Gas Electric Light and Power Co. of Baltimore. *2 Claims.*

The method covers the steps of initiating and adjusting the flow of preheat

IMPROVED ALUMINUM PISTONS

MADE POSSIBLE WITH G-E INERT-ARC WELDING

No. 3 in a series—demonstrating the potentialities of the G-E Inert-Arc process for solving difficult welding problems.

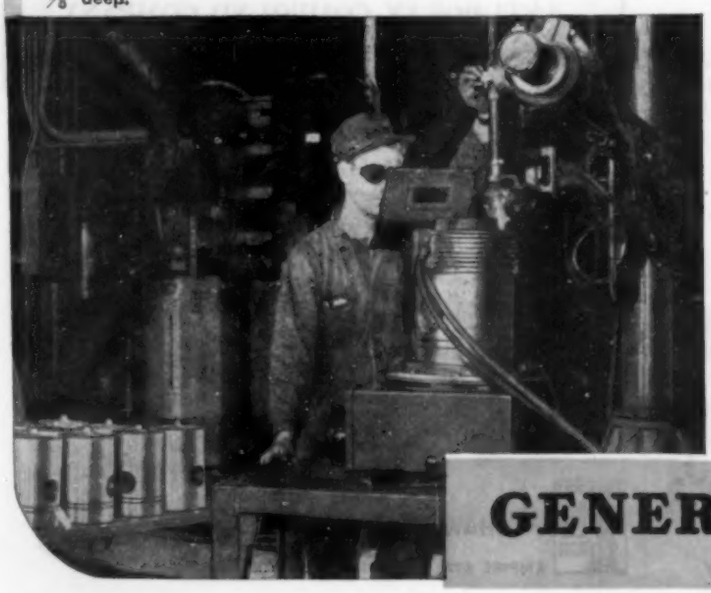
Inert-Arc welding is characterized by the shielding of the arc with an inert gas, such as argon or helium. On this job, tolerances were maintained within 3 mils, thus making further machining unnecessary, although the weld was within ¼" of the edge of the ring, and penetration was ⅜" deep.

Aluminum can and is being welded successfully in production—without flux!

●Diesel engine performance is improved, and weight materially reduced by the use of oil-cooled aluminum pistons. But operating difficulties might develop if the expanding gases within the cylinder should force their way between the body of the piston and a cooling and lubricating ring (also aluminum) shrunk-fit around the piston head.

Welding seemed the logical method for sealing permanently the ring to the piston, but rigid specifications had to be met. Absolutely no porosity could be tolerated. The joint design made it imperative to avoid the use of flux and the problem of its removal. Deep penetration was necessary to provide a durable seal. And while the weld was within ¼" of the edge of the ring, tolerances must not be seriously affected.

The manufacturer's welding engineers and General Electric's welding application group agreed shortly upon the solution—the Inert-Arc process. The above requirements were met successfully, and time for the operation was even less than expected.



You, too, can weld these so-called "difficult" metals—

—aluminum, stainless and cold-rolled steels, copper and special alloys. The fee for licensing under the basic General Electric patents has been reduced to $200. Your G-E Welding Distributor will be glad to assist with your welding problems. Give him a call! *General Electric Company, Schenectady 5, N. Y.*

●

With machine-welding equipment, consisting of a single welding head mounted on a radial arm for flexibility, this particular operation required only a single pass and no filler metal. The water-cooling jacket helps dissipate excess heat

●

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GENERAL ELECTRIC

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oxygen and fuel to provide a predetermined oxygen pressure at the inlet of the torch tip, initiating the flow of cutting oxygen, and then increasing the oxygen pressure at the source to restore the predetermined oxygen pressure at the torch tip inlet. Next the flow of cutting oxygen is discontinued and the flow of preheat oxygen is throttled at an additional valve to restore the predetermined oxygen pressure at the torch tip inlet, which additional valve is by-passed when cutting oxygen flows whereby the predetermined oxygen pressure is maintained at the tip inlet when preheat oxygen alone flows or when it and cutting oxygen flow.

2,400,249—WELDING ROD; Raymond L. Morrison, *Inventor;* Buffalo, N. Y.; assignor to Morrison Railway Supply Corp. *4 Claims.*

Morrison's welding rod is for use in welding manganese steel and the rod comprises from 5 to 20% manganese, copper and nickel together in a total amount from 1 to 5%, boron from 0.001 to 0.1%, carbon from 0.1 to 2%, silicon from 0.1 to 2% and the balance essentially iron.

2,400,285—WELDER'S ELECTRODE HOLDER—Robert H. Buck, *Inventor;* Oakland, Calif. *3 Claims.*

This patented holder has an insulated handle with a threaded contact rod projecting therefrom. An insulated tubular member adjustably engages with the contact rod and carries movable jaws in such a manner that the members' engagement controls the jaw action.

2,400,473—PORTABLE WELDING GUN; Harold A. Strickland, Jr., *Inventor;* Detroit, Mich.; assignor to Budd Wheel Co. *6 Claims.*

The gun includes a transformer casing, a pair of electrode holders and a motor including a power element which motor and electrode holders have a support that mounts them on one side of, and adjacent, the casing. One of the electrode holders is pivotally attached to the support and has an actuator for engaging with the power element while a spring device is provided for returning the electrode holder to its open position when released by the power element.

2,400,480—FACE PROTECTING HELMET; Charles E. Bowers, *Inventor;* Moylan, Pa.; assignor to The Fibre-Metal Products Co. *5 Claims.*

This helmet is adapted to be moved about a horizontal axis on a head engaging member. The helmet has a window in it and a plurality of pivot points are provided to vary the vertical position of the window with relation to the eyes of the wearer

Employment Service Bulletin

SERVICES AVAILABLE

A-517. Welding Engineer now available. Welding Superintendent for past six years with Consolidated Steel Corporation, Orange, Texas, building destroyers. 10 years Senior Welding Engineer for Navy Yard. 6 years Welding Engineer with General Electric Co. Graduated from Pennsylvania State College 1916, M.E. Degree.

A-523. Combination Arc and Gas Welder. Twenty-two years' experience at both Arc and Gas (combination) welding. Have held positions of supervisory capacity, such as: Foreman, Supervisor, Instructor and Snapper. Perfectly willing to work in the New England States if cannot be placed in New York.

A-524. Arc and Gas Welder. 18 years' practical experience in Arc and Acetylene welding and burning. Pipe work, structural steel, railroad maintenance, earth moving, rock crushing equipment, tank and pressure work. Background: foundry molder, welder, welding engineering, metallurgy, X-ray, radiography training in Extension Department of University of Minnesota. Welding Instructor in Defense Program. Seeks employment where experience and education provide wider scope and opportunities. Age 41. References.

A-525. Young man presently employed as electrode formulator and research engineer seeks new position as formulator or production control engineer. Familiar with all types of electrodes, but majority of work connected with stainless steel electrode development. Thoroughly experienced with specifications and welding tests.

INCREASES EFFICIENCY 20%

GARIBAY '350'

350 AMPERES CONTINUOUS CONDUCTIVITY

ELECTRODE HOLDER
PATENTED

Light weight, fully insulated
Full view of work
Natural welding position
Scientifically ventilated
Ideal mechanical cable connection

Distributors Wanted
Write in for Territories

GARIBAY MANUFACTURING CO.
1517 COLEGROVE AVE., MONTEBELLO, CALIF.

"Welding Tools Designed for Efficiency"

Buy "Proven Fluxes" with Years of Guaranteed Satisfaction behind them
The Trade-Name is "ANTI-BORAX"

Ask for Them ***Unequalled for Quality***

A Flux for every metal: Cast Iron Welding Flux No. 1; Brazing Flux No. 2; Braz-Cast Flux No. 4 for bronze-welding cast iron; "ABC" Aluminum Flux No. 8 for sheet Aluminum and all alloys of Aluminum; Stainless Steel Flux No. 9; Silver Solder Brazing Flux No. 10; No. 16 Silver Solder Paste Flux.

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Time Counts—
Gas cut and Weld with

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PAGE *Gas* WELDING RODS

PAGE now offers two new bronze rods for oxyacetylene welding – both up to the well-known PAGE high standard of quality and uniformity. Each of these rods has many applications in maintenance and production. For specific information about these – or any other type of electrode or gas welding rod – get in touch with your PAGE distributor.

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PAGE STEEL AND WIRE DIVISION
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SECTION ACTIVITIES

CINCINNATI

The May meeting of the Cincinnati Section was held on the 8th at the Engineers' Club. Guest speaker for the evening was J. M. Wilson of the Metal and Thermit Corp. Mr. Wilson's subject was "Welding of Stern Frames on Liberty and Victory Ships." A motion picture and slides were used to illustrate the talk.

The customary Dutch lunch was served to members and guests after the meeting.

CLEVELAND

Newly elected officers for the coming year are:

Chairman, Kent Thornton, American Ship Building Co.; *1st Vice-Chairman*, Mike Shane, Cleveland Electric Illuminating Co.; *2nd Vice-Chairman*, Arthur Portz, Cleveland Welding Co.; *Secretary-Treasurer*, Joe Wagner, Burdett Oxygen Co.

Work by the Cleveland Section Building Code Committee over a period of a great many years is finally coming to fruition. The Mayor of Cleveland recently requested the City Council and the Building Commissioner to completely revise Cleveland's building code, and at the present stage it appears that the new American Institute of Steel Construction codes covering riveting, bolting and arc welding will be incorporated as standard sections of the Cleveland Code. Under the capable leadership of Frank Maine, the AMERICAN WELDING SOCIETY has taken the lead in getting the backing of other engineering groups in Cleveland to push for the A.I.S.C. standard code.

DAYTON

The final business session of the season was held on Wednesday, May 22nd, at The Engineers' Club. Two films were shown, the first being a six-part movie, "The Inside of Arc Welding," shown through the courtesy of the General Electric Co. The second half of the double feature was "How Not to Conduct a Meeting," starring Al Mealey, impersonated by Colonel Lemuel Q. Stoopnagle.

DETROIT

Newly elected officers of the Detroit Section are as follows:

Chairman, A. H. Lewis, Swift Electric Welder Co.; *Vice-Chairman*, A. J. Last, Welding Sales & Engineering Co.; *2nd Vice-Chairman*, J. R. Stiff, R. C. Mahon Co.; *Secretary-Treasurer*, E. B. Brown, The American Brass Co.; *Assistant Secretary*, J. H. Colwill, National Cylinder Gas Co.

HARTFORD

The following officers have been elected by the Hartford Section for the coming season:

Chairman, Shaw Taylor; *Vice-Chairman*, E. Flynn; *Secretary*, R. H. Florian; *Treasurer*, L. Koch; *Program Chairman*, S. Adelson; *Membership Chairman*, S. Zenczak. *Directors:* R. Lautier, H. Fordyce, F. Giroux, J. W. Mortimer, R. Studzinski, E. Thurz.

The May meeting held on the 23rd included an inspection trip to The Whitlock Manufacturing Co., Elmwood, Conn., followed by dinner at The Garde Hotel. Speaker at the evening session was Arthur N. Kugler, Mechanical Engineer, Technical Sales Division, Air Reduction Sales Co. Mr. Kugler spoke on "Jigs and Fixtures for Welding."

INDIANA

The Indiana Section presented the General Electric Co.'s "House of Magic" an hour and a half demonstration of starting new scientific developments, on May 7th at the Shortridge High School.

KANSAS CITY

T. B. Jefferson, Editor of *The Welding Engineer*, discussed "Structure Welding," at the June 4th meeting held in the Masonic Temple.

LOS ANGELES

Regular monthly meeting held at Scully's Cafe on May 16th. Leon C. Bibber, Welding Engineer, Carnegie Illinois Steel Corp., made a special trip to Los Angeles, and spoke on the subject "The Elements of Welded Design," which was most interesting and was supplemented by slides showing the various types of design necessary to get the most out of welding. Mr. Bibber's talk was not only very enlightening but it was also entertaining.

LOUISVILLE

The first Welding Conference sponsored jointly by the Louisville Section of the A.W.S. and the University of Louisville was held on Wednesday, May 22nd, afteroon and evening, at the University of Louisville. It was very well attended and it is planned to make it a yearly event.

The afternoon session consisted of demonstrations by several companies and a paper presented by E. F. Schulz, Louisville & Nashville R. R. Co., on "Oxy-acetylene Cutting and Welding of Heavy Sections."

The evening session also consisted of demonstrations by several companies and a paper by G. C. Williams, Chemical Engineering Dept, University of Louisville, on "Metallurgy of Welding."

MAHONING VALLEY

The May meeting was held at the Warner Hotel, Warren, Ohio. Dinner was served to 114 members and guests, after which B. L. Wise, District Vice-President, gave an interesting talk on the objectives of the AMERICAN WELDING SOCIETY in general.

Through the courtesy of the Federal Machine & Welder Co., the group was entertained for about one hour with the showing of two very interesting films. The first of these showed the forming and resistance welding of chain and the second picture showed the development of one of the tanks manufactured by Federal during the war.

Following the dinner meeting at the hotel, about 150 members and guests were conducted on tours through the plants of the Federal Machine and Welder Co. and the Warren City Manufacturing Co.

MARYLAND

"Amateur Night or Welding Can Be Fun" was the subject of the May 17th meeting held at the Engineers' Club, Baltimore. After dinner a sound technicolor film entitled "This is Resistance Welding," prepared by the General Electric Co., illustrating the equipment and many applications of this high-speed production process, was shown.

The Quiz Session which followed consisted of a group of experts who gave the audience a list of questions to be answered true or false. Then the group gave the correct answers and explained the pros and cons of each question. The board of experts consisted of: L. Barrett, The Glenn L. Martin Co.; G. E. Claussen, the Reid-Avery Co., J. W. Gore, The Bethlehem Steel Co.; H. H. Hunt, The American Bureau of Shipping, and G. E. Linnert, The Rustless Iron & Steel Corp.

MICHIANA

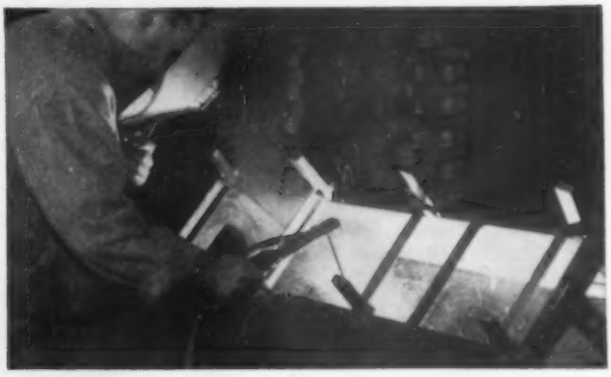
The May 17th meeting of the Michiana Section was held at the Y.M.C.A., South Bend, Ind. Dinner at the Offman Hotel preceded the meeting. Omer Blodgett, Welding Engineer, The Lincoln Electric Co., Grand Rapids Office, spoke on "Why Convert to Welded Construction." Actual weldments were used to illustrate the talk. A new sound colored movie,

(*Continued on page 676*)

HERE, MR. HAMBRO, are results obtained with an instrument for faster welding at lower cost:

Results with "Fleetweld"

Going downgrade 33% faster. This fabricator was welding corner joints in 18 gauge galvanized steel at an arc speed of 30" per min. At the suggestion of the Lincoln Engineer, he started tilting the joint 45° and welding downhill with "Fleetweld 35". Increased speed to 40" per min. . . . 33% faster.



Jigging up for 16% lower cost. Use of jigs to improve fit-up of parts and positioners to get downhand welding usually permits use of larger electrodes. In welding of this tapping machine frame, electrode size went from 5/32" to 3/16" "Fleetweld 7". Welding cost went down 16%.

Using "arc force" to boost speed 20%. Fillet welds in flat and horizontal positions are being made with ¼" "Fleetweld 11" and "Fleet-Fillet" Technique at arc speeds of 12" per min. where former method gave 10" per min. This mining machine transmission case is a typical application. Full details in Bul. 444.

The sign of good results. When you see 3 DOTS on an electrode, you know you have genuine "Fleetweld" . . . the world's leader for *low cost, speed* and *quality*. New, handy pocket manual giving procedures for all kinds of jobs free on request. Ask for Bul. 437.

New Lincoln sound-color movies available free for showing to groups. Write for information.

THE LINCOLN ELECTRIC COMPANY • DEPT. 54 • CLEVELAND 1, OHIO

America's greatest natural **recourse**

ARC WELDING

entitled "Prevention and Control of Distortion in Welding," was shown through the courtesy of The Lincoln Electric Co.

MILWAUKEE

Annual Dinner Dance "Get-Together" was held by the Milwaukee Section on May 25th at the Plankinton Hotel.

NEW YORK

The following are the newly elected officers and members Executive Committee of the New York Section.

Chairman, E. B. Stolle, Midwest Piping & Supply Co.; *1st Vice-Chairman*, H. R. Morrison, The Linde Air Products Co.; *2nd Vice-Chairman*, H. W. Northcutt, Bethlehem Steel Co.; *Secretary-Treasurer*, L. F. Granger, The Linde Air Products Co. *Members-at-Large:* (three-year term) G. L. Baker, O. H. Henry, H. W. Lawson, E. Vom Steeg, Jr.; (two-year term) E. V. David, W. A. Howard, Charles Kandel, J. L. Wilson; (one-year term) J. L. Cahill, J. L. Lufkin, G. W. Place, E. H. Roper.

Junior Past Chairmen, H. O. Klinke, G. V. Slottman, G. Schneider.

NORTHWEST

At the Ninth Annual Meeting of the Northwest Section held Thursday, May 16th, at the Covered Wagon, Minneapolis, the following officers and members of the Executive Committee were elected.

Chairman, R. H. Newton, The Lincoln Electric Co.; *Vice-Chairman*, E. E. Hall, Flour City Welding Co.; *Secretary-Treasurer*, Alexis Caswell, Manufacturers Association of Minneapolis, Inc. *Executive Committee:* E. L. Hixson, L. T. Kenny, Warren F. Logemann, Melvin Ovestrud, R. H. Schleuder, F. W. Scott, R. J. Stoddard, H. R. Toll, C. M. Underwood.

R. E. McFarland, the District Vice-President, spoke briefly on the activities of the SOCIETY. The speaker of the evening was G. O. Hoglund, Aluminum Co. of America, New Kensington, Pa., who spoke on "Welding Aluminum." His talk was illustrated with slides and motion pictures.

PHILADELPHIA

The May meeting of this Section was held on the 20 that the Engineers' Club. "Welding of Special Steels and Alloys" was the subject of the talk presented by A. B. Kinzel, Vice-President, Union Carbide and Carbon Co.

OKLAHOMA CITY

Annual Stag Party held by the Oklahoma City Section took place this year on June 7th at the Belle Isle Park Dance Pavilion. Guest speaker was T. B. Jefferson, Editor, *The Welding Engineer*, Chicago, who spoke on "Structural Welding."

PASCAGOULA

Dinner meeting of the Pascagoula Section was held on Tuesday, May 21st, at the Country Club. The speaker for the event was David Bannerman, Jr., a member of the technical staff of the American Bureau of Shipping, New York City, who addressed the group on "Ship Failures and the Remedies Thereof." More than 100 members and guests enjoyed Mr. Bannerman's talk.

PORTLAND, OREGON

Portland, Oregon Officers Standing in Picture Left to Right: Paul Chatterton, Vice Chairman; Vincent J. Shanahan, Treasurer; Paul Kullberg, 1946 Chairman; B. A. McLean, Retiring Chairman; Dr. Wendall F. Hess, National President, A.W.S.; Jack W. Donnelly, Program Chairman; Joe Crumley, Secretary seated 2nd from left in front of Mr. Kullberg

PUGET SOUND

The following officers were elected at the Annual Meeting held May 28th by the Puget Sound Section for the coming year:

Chairman, Gilbert S. Schaller, University of Washington; *Vice-Chairman* Myron D. Stepath, Bremerton, Wash.; *Secretary-Treasurer*, H. O. Van Slyke, Air Reduction Sales Co. *Executive Committee:* George Brett (to finish one-year term vacated by Mr. Van Slyke, newly elected Secretary-Treasurer); (two-year term) A. W. Webster, George Morrisey, Harold Moe.

SAINT LOUIS

"Welding in Transportation" was the subject of lecture and discussions presented by William G. Boese, Welding Engineer, Pullman Standard Car Mfg. Co., Hammond, Ind., at the May 17th meeting held at the Engineers' Club. Mr. Boese's talk covered the creepage allowance in welding of High Tensile Low-Alloy Steels in the fabrication of freight cars.

SAN FRANCISCO

The following officers were elected by the San Francisco Section at their April 22nd meeting:

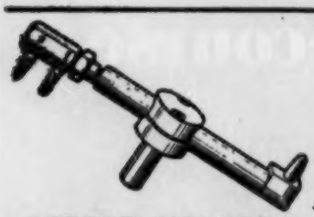
Chairman, Mark Haines, Mark Haines Welding Shop; *Vice-Chairman*, L. P. Henderson, The Lincoln Electric Co.; *Second Vice-Chairman*, F. T. Patton, Standard Oil Co.; *Secretary*, Richard E. Labagh, Victor Equipment Co.; *Treasurer*, P. H. Bertola, Harnischfeger Corp. *Executive Committee:* Leo Berner, Charles S. Smith, Harold L. Saunders.

The May meeting held on the 27th was addressed by L. C. Bibber, Welding Engineer, Carnegie-Illinois Steel Corp., who spoke on "The Various Welding Processes and the Relation Between Them." Mr. Bibber's talk enlightened many present to a number of welding processes of which they were formerly unaware. A color motion picture with sound, entitled "This Is Resistance Welding," followed Mr. Bibber's talk.

SOUTH TEXAS

The South Texas Section met in regular session in Houston on Tuesday, May 7th, and heard a very interesting and complete discussion of welding processes in use today. Leon C. Bibber, Welding Engineer, Carnegie-Illinois Steel Corp., Pittsburgh, was the guest speaker, and his

(*Continued on page 680*)



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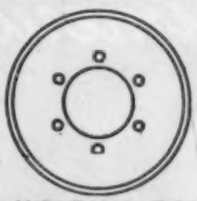

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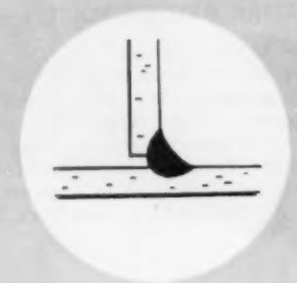
THE ELECTROLOY CO. INC. 1600 SEAVIEW AVE. BRIDGEPORT, CONN. WELDING ROLL

for Faster Welding

JUST "DRAG" THE ELECTRODE

Welding is easier with "FW". No arc gap to worry about. Electrode actually "rides" on its coating. Fatigue is reduced. Operators weld better and faster.



FAST FREEZING

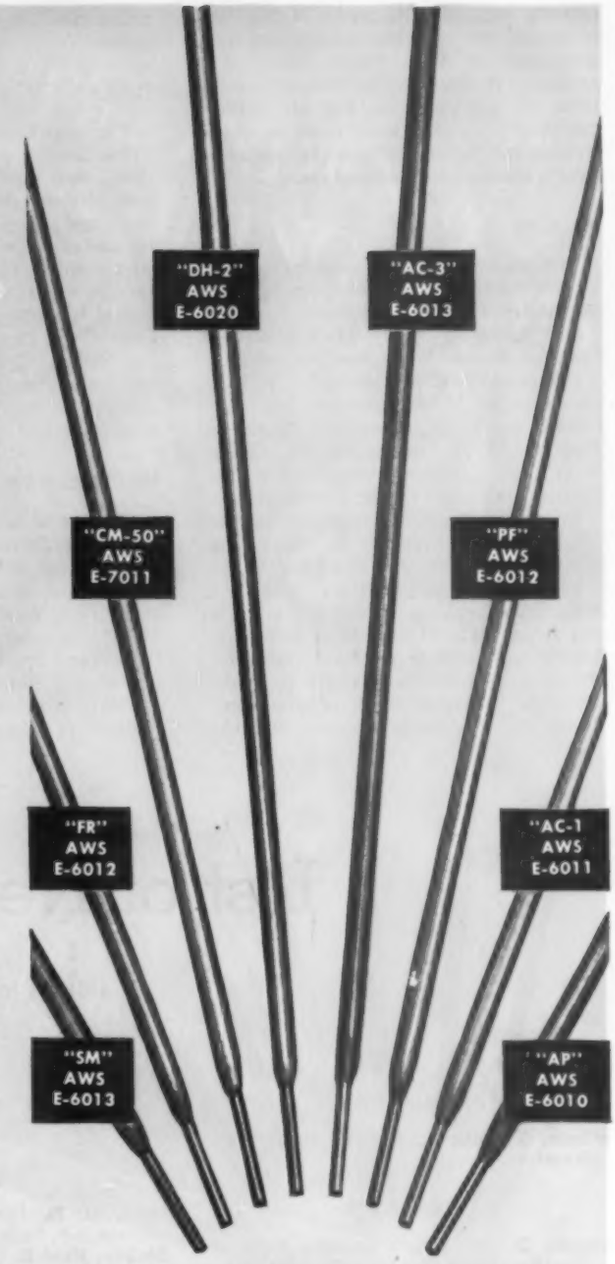
Poor fit-ups are no problem with "FW". Its fast freezing means better results. You get fine concave fillets—smooth appearance.

OUT-OF-POSITION WELDING

Although "FW" is a downhand electrode, it can also be used for out-of-position welding by experienced operators. This saves more time — is another reason for its wide acceptance.

GOOD APPEARANCE

You get smooth, uniform welds with "FW" — even over irregular and poor-fit joints. It's the ideal electrode for machine bases, farm and road machinery, structural work, etc.



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Whatever your welding needs, you can choose the correct types and sizes from the complete P&H line. Above are shown a few of the P&H mild steel group. A complete line for welding stainless and alloy steels, as well as for hard surfacing, is also available.

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P&H makes a production-proved electrode for every welding requirement: for all mild, alloy and stainless steel applications cast iron and for building up and hard surfacing.

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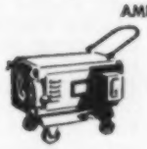
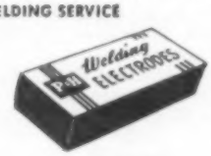


DC WELDERS

AC WELDERS



WELDING ELECTRODES

WELDING POSITIONERS

WELDING PRODUCTION CONTROL SYSTEMS

ELECTRIC HOISTS

remarks included a discussion of the principles and uses of all the welding processes developed to date. Slides and charts were used to illustrate the various applications of these processes, and Mr. Bibber mentioned several special cases in which welding was being used to make repairs to large machinery sections and gears.

TOLEDO

The season of regular meetings of the Toledo Section closed with an Annual Meeting on Tuesday, May 14th.

The following newly elected officers and members-at-large were introduced: *Chairman*, John C. Geisland; *1st Vice-Chairman*, C. M. Richardson; *2nd Vice-Chairman*, E. V. Newman; *Secretary-Treasurer*, A. H. Homrighaus, Jr. *Member-at-large:* (three years) Anthony Menna; (one year) Van S. Wielosinski.

The technical subject of the evening was "Welding and Brazing the Aluminum Alloys," very ably presented by G. O. Hoglund, Welding Engineer with the Aluminum Company of America. A 16-mm. sound film, "How to Weld and Braze Aluminum," and in addition slides for typical application were used to make clear the different kinds of aluminum alloys, the weldability of same and the techniques employed for welding these metals.

TULSA

The regular monthly meeting of the Tulsa Section was held on May 10th at the Leland Equipment Co. Paul Butterfield, Nelson Sales Corp., Lorain, Ohio, presented a demonstration of stud welding and also described the various types of stud welding, which were illustrated by a twenty-minute moving picture.

Ted B. Jefferson, Secretary and Treasurer of the Chicago Section, and Editor, *The Welding Engineer*, gave an illustrated talk on the methods of Structural Welding, at the June 6th meeting held at the Mayo Hotel.

WESTERN NEW YORK

Election of 1946–47 officers and directors of this Section took place at the April 26th meeting, as follows:

Chairman, Ken Kopman; *Vice-Chairman*, Dick Lyall; *Secretary*, Ogden C. Mills; *Treasurer*, Bob Siemer. *Directors* (two years) Ben H. Grimes, L. Fitzgerald; (one year) I. Morrison.

The speaker of the evening was A. K. Phillipi of the Westinghouse Electric Corp., whose subject was "Furnace Brazing."

WICHITA

The Wichita Section hed their regular monthly meeting on May 8th. The officers and members of the Executive Committee held a luncheon and business meeting prior to the regular meeting at the Broadview Hotel.

The regular meeting was held at the plant of the B and G Manufacturing Co. The speaker of the evening was Paul Butterfield of The Nelson Sales Corp. of St. Louis, Mo. Mr. Butterfield gave a demonstration of stud welding equipment and described various types of stud welding. The lecture was accompanied by a moving picture in color.

CANADIAN WELDING SOCIETY

The Montreal Chapter of the above society held its last meeting of the 1945–46 season on Monday, May 20th, in the Auditorium of the Montreal Technical School. "Pressure-Welding by the Oxy-acetylene Process" was presented by C. J. Burch, Development Engineer, The Linde Air Products Co., New York, N. Y.

List of New Members

May 1 to May 31, 1946

BRIDGEPORT

Wilson, Thomas A. (C), 90 Sands Pl., Stratford, Conn.

CANADA

Alcock, D. M. (B), Canadian General Electric Co., Ltd., 212 King St. W., Toronto L., Ont., Canada.

CHICAGO

Bright, Thornton F. (B), 1400 Lake Shore Dr., Chicago 10, Ill.
Cahoon, R. C. (B), c/o Hollup Corp., 4700 W. 19th St., Chicago 50, Ill.
Ebert, Lloyd W. (C), 108 Gardena St., Michigan City, Ind.
Geise, Theodore (C), 2512 Cullom Ave., Chicago 18, Ill.
Kulan, Michael T. (B), 11306 S. Edbrooke Ave., Chicago 28, Ill.
Lee, Virgil E. (B), 1039 W. 45th Ave., Gary, Ind.
Lloyd, Reese B. (B), Rheem Mfg. Co., 7600 S. Kedzie Ave., Chicago 29, Ill.

CLEVELAND

Olds, Roy L. (C), 1952 Laurelhill Dr., South Euclid, Ohio.

COLUMBUS

Zambrow, John L. (C), Battelle Memorial Inst., 505 W. King Ave., Columbus 1, Ohio.

DAYTON

Case, O. D. (B), 3660 Vermont Ave., Dayton 6, Ohio.
Smiley, Paul E. (B), John G. Pool, Inc., 494 Commercial Bldg., Dayton 2, Ohio.

DETROIT

Falberg, Fred R. (B), 983 Chester, Birmingham, Mich.
Farnsworth, Grover C. (B), General Motors Truck & Coach Div., Plant 2, South Blvd., Pontiac 11, Mich.
Gandy, Harold W. (C), General Motors Truck & Coach, Welding Engrg. Dept., Plant 2, 660 South Blvd. E., Pontiac 11, Mich.
Miller, C. A. (B), Welding Engrg. Dept., General Motors Truck & Coach Div., Plant 2, South Blvd., Pontiac 11, Mich.
Mumford, William E. (B), General Motors Truck & Coach Div., Welding Engrg. Dept., Plant 2, South Blvd., Pontiac 11, Mich.
Olson, Bert T. (B), 1466 Oakwood, Pontiac 19, Mich.
Patton, Walter G. (B), *Iron Age*, 403 Blvd. Bldg., Detroit 2, Mich.
Taylor, M. H. (B), Whitehead & Kales Co., 58 Haltiner Ave., River Rouge, Mich.
Wheeler, Neil E. (B), Welding Engrg. Dept., General Motors Truck & Coach Div., Plant 2, South Blvd., Pontiac, Mich.

HARTFORD

Flynn, Edwin N. (C), 9 Drive "E," Silver Lane Homes, Manchester, Conn.

INDIANAPOLIS

Gilyeat, Ernest F., Jr. (C), Allied Weldcraft, Inc., 401 W. South St., Indianapolis, Ind.
Graham, Phillip E. (B), Weltronic Co., 527 Peoples Bank Bldg., Indianapolis 4, Ind.
Humphrey, R. I. (B), Mouldings, Inc., 730 E. Washington St., Indianapolis, Ind.

KANSAS CITY

Lamb, Geo. W. (C), American Inst. of Steel Const., Inc., 620 New England Bldg., Topeka, Kans.

LEHIGH VALLEY

Bodine, Robert Y. (C), 314 Wall St., Bethlehem, Pa.

LOS ANGELES

Bennett, Alvin L. (B), 1723 Newell St., National City, Calif.

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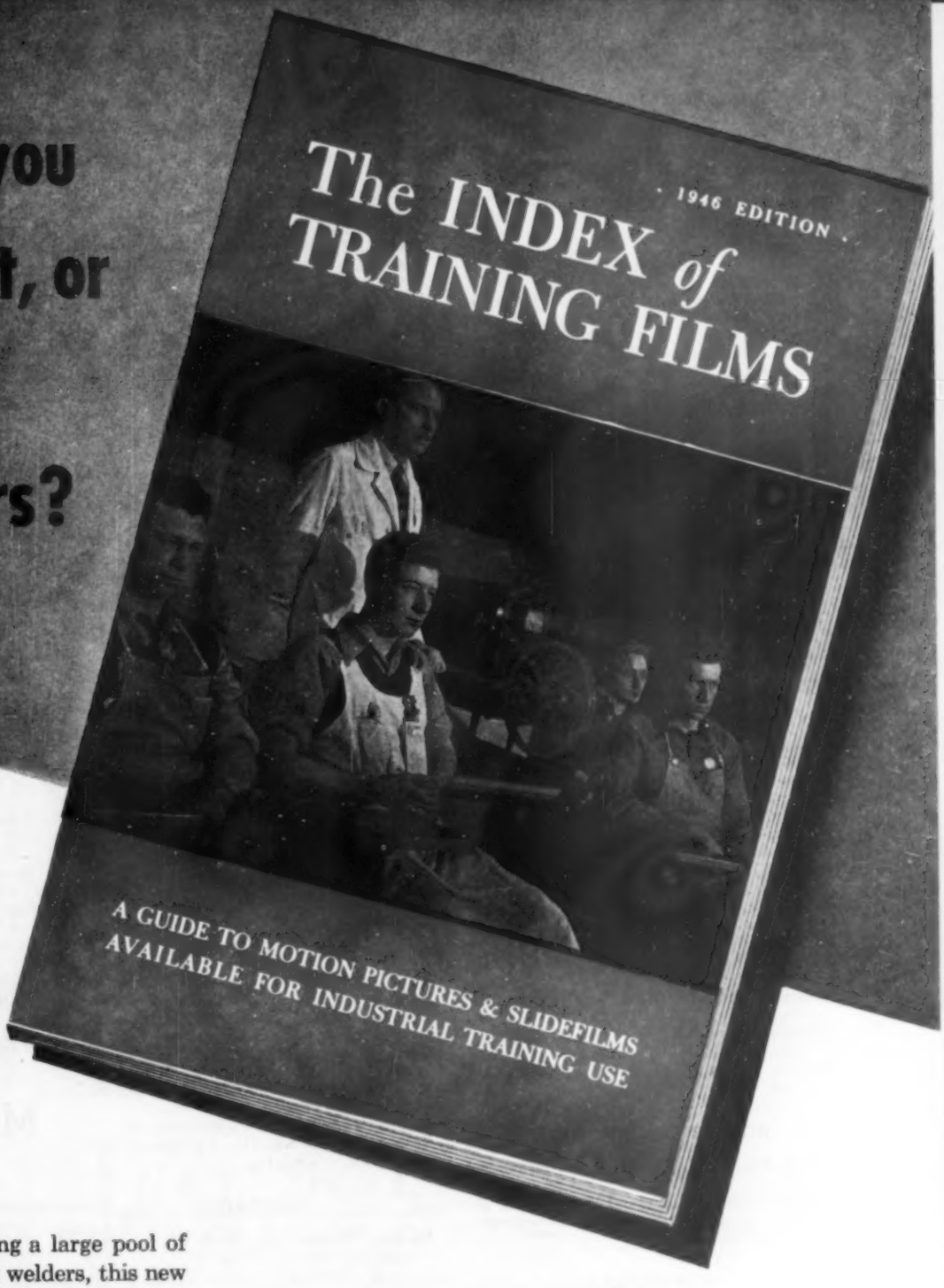

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Force, Earl (B), 302 S. Center St., Newton Falls, Ohio.
Headley, Lewis M. (B), 2629 South St., Warren, Ohio.
Kriebel, Isaac H. (C), 129 Elm St. N. E., Warren, Ohio

MARYLAND

Barnett, James David (C), 401 S. Cornwall, Baltimore 24, Md.
Barrett, Robert L. (C), 5201 Pembroke Ave., Baltimore 6, Md.
McCormack, Bernard (C), Stevenson & Valley Rd., Stevenson, Md.
Montaigne, Howard R. (C), District Welding Supply Co., 3235 Rhode Island Ave., Mount Rainier, Md.
Palange, John R. (C), 919 Short Rd., Dundalk 22, Md.
Smith, Harry G. (C), 4510 Kenwood Ave., Baltimore 6, Md.

MICHIANA

Whittaker, Ralph (C), American Fdry. Equip. Co., Mishawaka, Ind.

NEW YORK

Collins, John F. (B), American Elec. & Welding Supply Co., 575 Atlantic Ave., Brooklyn 17, N. Y.
Doyle, John F. (C), Welding Engr., 330 W. 42nd St., New York 18, N. Y.
Ellison, Robert A. (C), Harnischfeger Corp., 30 Church St., New York, N. Y.
Hildum, Norman F. (C), Ward La France Truck Div., Great American Industries, Elmira, N. Y.
Kwang-Hwa, Lee (B), c/o Min-Dah Young, Bank of China, 40 Wall St., New York, N. Y.
Makowski, Albert J. (B), 1449 Flatbush Ave., Brooklyn 10, N. Y.
Schein, Albert R. (C), 106-12—107th Ave., Ozone Park 16, L. I., N. Y.
Tesmen, Arthur B. (C), North American Philips Co., Dobbs Ferry, N. Y.
Theurer, Ernest E. (C), 1840 E. 26th St., Brooklyn, N. Y.
Zeisel, Albert E. (B), 400 E. 52nd St., New York, N. Y.

NORTHERN NEW YORK

Craig, Allen G. (C), 12 Trinity Pl., Amsterdam, N. Y.
Richter, Chas. (C), Modern Welding & Heating Co., Inc., 1740 Broadway, Schenectady 6, N. Y.

NORTHWEST

Olson, Harold E. (B), 2805 Grand Ave. S., Minneapolis 8, Minn.
Wheeler, Lawrence H. (B), 422 Hatch Ave., St. Paul 3, Minn.

NORTHWESTERN PA.

Anderson, Leroy J. (C), 238 E. 27th St., Erie, Pa.

OKLAHOMA CITY

Cupp, Jack (C), Black, Sivalls & Bryson Tank Co., c o Met. Dept., 2131 Westwood Ave., Oklahoma City, Okla.
Harman, Don W. (B), Oklahoma City Hdwg., 29 E. California, Oklahoma City, Okla.
Jones, Frank P. (C), 2016 N. W. 11th St., Oklahoma City, Okla.
Phillips, John C. (C), Herb Welding & Radiator Co., 1016 N. Broadway, Oklahoma City 2, Okla.
Poe, R. E. (C), Herb Welding & Radiator Co., 1016 N. Broadway, Oklahoma City 2, Okla.

PASCAGOULA

Aikens, J. W. (C), 1002 Buena Vista St., Pascagoula, Miss.
Cornelius, H. E. (C), 602 13th St., Pascagoula, Miss.
Franklin, J. N. (C), 821 Croesus St., Biloxie, Miss.
Jones, M. H. (C), 205 S. Hague St., Pascagoula, Miss.
Leach, Ray D., Jr. (C), 617 Columbus Dr., Pascagoula, Miss.
Millikan, Harold J. (C), 1401 Tyler Ave., Pascagoula, Miss.
Peddicord, Fred H. (C), U. S. Engineer Inspector Office, c/o Ingalls Shipbuilding Corp., Pascagoula, Miss.
Schillereff, John (C), P. O. Box 341, Pascagoula, Miss.
Williams, L. C. (C), 1111 Williams St., Pascagoula, Miss.

PEORIA

Arnold, E. L. (C), 1613 W. Glenn Ave., Peoria, Ill.
Doyle, Bert D. (C), R. F. D. 5, E. Peoria, Ill.

PHILADELPHIA

Wood, Thos. G. (C), 5019 Westwood Lane, Pennsauken Township, N. J.

PITTSBURGH

Coughlin, James P. (B), Westinghouse Electric Corp., E. Pittsburgh, Pa.
Detlor, Leonard T. (C), 4136 Gladstone St., Pittsburgh 7, Pa.
Gier, John R., Jr. (B), Ferrotherm Co., 4911 Butler St., Pittsburgh 1, Pa.
Koch, Joseph William (B), 148 Boyer St., Johnstown, Pa.
Leffler, Rudolf H. (B), Geistown, Pa.
Varner, Kenneth R. (B), Bethlehem Steel Co., Johnstown, Pa.

PORTLAND

Backus, Wayne (B), 2705 N. E. 52nd, Portland, Ore.

PUGET SOUND

Seidelhuber, Frank (B), Seidelhuber Iron & Bronze Works, Inc., 1421 Dearborn, Seattle, Wash.

ST. LOUIS

Weigel, John Henry (B), Combustion Engrg. Co., Inc., Heine Boiler Div., 5319 Shreve Ave., St. Louis, Mo.

SAN FRANCISCO

Moore, G. Frank (B), 340 Laurel Ave., San Anselmo, Calif.

TIDEWATER

Mosier, E. L. (C), Box 5091, South Norfolk, Va.

WESTERN MASS.

Taupier, Alex (C), Alexander Grant & Son, Inc., 153 Dwight St., Springfield, Mass.

YORK-CENTRAL PA.

Charlton, Edward J. (A), Lukens Steel Co. Coatesville, Pa.

NOT IN SECTIONS

Black, William C. (B), 48 Belstead Ave., Ipswich, Suffolk, England.
Craig, Robert B., Jr. (B), Hendrie & Bolthoff, 1635—17th St., Denver, Colo.
Fryer, Herbert E. (C), Carnegie-Illinois Steel Corp., 617 First National Bank Bldg., Denver 2, Colo.
Graham, Marlton E. (C), 507 S. Mesa, Carlsbad, N. Mex.
Griffiths, John D. (C), American Institute of Steel Const., 300 Brandeis Theatre Bldg., Omaha, Neb.
Jones, Dan W. (C), Le Tourneau Co. of Ga., Miss. Plant, P. O. Box 1031, Vicksburg, Miss.
Klodt, Herbert B. (B), 1577 W. Alameda Ave., Denver 9, Colo.
Maroni, Jose (B), Maroni Hermanos & Cia, 24, De Noviembre No. 1763-69, Buenos Aires, Argentina, S. A.
Nelson, Manley Robert (B), General Iron Works Co., P. O. Box 2490, Denver, Colo.
Rosenbach, Aleck (C), 3600 Race St., Denver, Colo.
Sheehan, Richard S. (B), General Iron Works, 600 W. Bates, Denver, Colo.
Tribe, Thomas Francis (B), The British Federal Welder and Machine Co., Ltd., Dudley Worcestershire, England.
Walker, Russell (C), Le Tourneau Co. of Ga., Miss. Plant, P. O. Box 1031, Vicksburg, Miss.

Members Reclassified

During Month of May

CANADA

Tetreault, J. (from C to B), c/o Marine Industries Ltd., Sorel, Que., Canada.

CLEVELAND

Barton, James R. (from D to C), 2790 East Blvd., Suite 55, Cleveland, Ohio.

DETROIT

Lenz, John J. (from D to C), 2630 Jackson St., Anderson, Ind.

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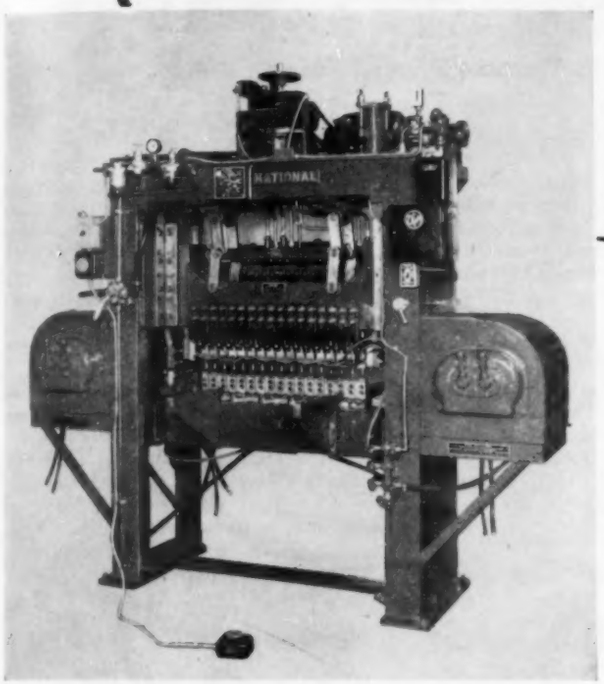

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Phone Parkway 2030

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631 Fisher Bldg.
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Phone Franklin 2381

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Phones Prospect 8806 and 1686

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National Cylinder Gas Co.
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Phone 8-4228

MINNEAPOLIS 2, MINNESOTA
Chas. W. Stone
1019 Marquette Ave.
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Patrick H. Dillon
524 Howard Ave.
Phone Raymond 1214

PHILADELPHIA 30, PENNSYLVANIA
K. Wm. Ostrom & Co.
1622 Fairmount Ave
Phone Stevenson 4672

ST. LOUIS 8, MISSOURI
Clements Welding Supply Co.
709 Academy Avenue
Phone Forest, 4950

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Canons of Ethics for Engineers*

Constituting a Standard of Professional Conduct for Members of the American Welding Society

Approved by the Board of Directors, AMERICAN WELDING SOCIETY, June 20, 1946

Foreword

Justice, courtesy, honesty and sincerity, associated with mutual interest between men, make the foundation of ethics. Ethics should be more than passive observance of a code of "Don'ts" in the life of an engineer. They should be recognized as dynamic principles guiding his conduct and his way of life. The principles are briefly set forth in what follows.

Professional Life and Employment

Sec. 1.—The Engineer will cooperate in building up the engineering profession by interchanging information and experience with other engineers and students and by contributing to the work of engineering societies, schools and the scientific and engineering press.

Sec. 2.—He will carry on his work in a spirit of fairness and loyalty to clients or employers, to associates, subordinates and employees, fidelity to the public interest and devotion to high ideals of courtesy and personal honor.

Sec. 3.—He will not advertise his work or merits in a self-laudatory manner and he will avoid all other conduct or practices likely to discredit or do injury to the dignity and honor of his profession.

Sec. 4.—He will not associate himself or allow his name to be associated with any enterprise until he has satisfied himself that it is of unquestionable and legitimate character.

Relations with Other Engineers

Sec. 5.—The Engineer will endeavor to protect the engineering profession collectively and individually from misrepresentation and misunderstanding.

Sec. 6.—He will take care that credit for engineering is attributed to those who, in so far as his knowledge goes are the real authors of the work.

Sec. 7.—He will maintain the principle that unduly low compensation for engineering work or employment tends toward impairing the quality of the results and is not in the public interest and is to the disadvantage of the individual engineer and to his profession.

Sec. 8.—He will not intentionally, directly or indirectly, injure the reputation or business of another engineer.

Sec. 9.—He will not try to supplant another engineer in a particular employment after becoming aware that definite steps have been taken toward the employment of the latter.

Sec. 10.—He will not compete with another engineer on the basis of charges for work by underbidding, through reducing his normal fees after having been informed of the charges named by the other.

Sec. 11.—He will not use personally the advantages of a salaried position to compete unfairly with another engineer.

Sec. 12.—He will not review the work of another engineer, for the latter's client or employer, without the other engineer's knowledge unless the latter's connection with the work has terminated.

Sec. 13.—He will not become associated in responsibility for work with engineers who do not conform to ethical practices.

Relations with Clients and Employers

Sec. 14.—The Engineer will act in professional matters for each client or employer as a faithful agent or trustee.

Sec. 15.—He will act in an attitude of fairness and justice between his client or employer and the contractor when dealing with contracts.

Sec. 16.—He will make his status clearly understood to his client or employer before undertaking an engagement if he may be called upon to decide on the use of inventions, apparatus, or any other thing in which he may have a financial interest.

Sec. 17.—He will regard it his duty to guard against dangerous elements on apparatus, structures, or plant or dangerous conditions of operation therein, and upon observing such conditions in work with which he is associated he will call them to the attention of his client or employer. He will not permit unsafe conditions to exist on work for which he is responsible.

Sec. 18.—He will present clearly the consequences to be expected from deviations proposed if his engineering judgment is over-ruled by nontechnical authority in cases where he is responsible for the technical adequacy of engineering work.

Sec. 19.—He will engage or advise his client or employer to engage and he will cooperate with other engineering experts and specialists whenever the client's or employer's interests are best served by such service.

Sec. 20.—He will treat as confidential his knowledge of the business affairs or technical processes of clients or employers when their interests so require.

Sec. 21.—He will not accept compensation, financial or otherwise, from more than one interested party for the same service, or for services pertaining to the same work, without the consent of all interested parties.

Sec. 22.—He will not accept commissions or allowances, directly or indirectly from contractors or other parties dealing with his client or employer in connection with work for which he is responsible.

Sec. 23.—He will not be financially interested in the bids as a contractor on competitive work for which he is employed as an engineer unless he has the consent of his client or employer.

Sec. 24.—He will not, without the full knowledge and consent of his client or employer, have an interest in any business which may bias his judgment regarding engineering work for which he is employed or which he may be called upon to perform, or have an interest in a business which may compete with the business of his client or employer.

Relations with the Public

Sec. 25.—The Engineer will interest himself in the public welfare and be ready to apply his special knowledge, skill and training for the benefit of mankind.

Sec. 26.—He will assist public officials and others in attaining a fair and correct general understanding of engineering matters, extend the public knowledge of engineering and discourage untrue, unfair and exaggerated statements regarding engineering.

Sec. 27.—He will recognize the fact that meetings of engineering societies and the engineering press provide a proper forum for technical discussions and criticisms, and also that clear statements of facts relating to engineering enterprises are sometimes of value to the public when they are prepared for laymen's understanding and released by competent authority through the public press.

Sec. 28.—He will make provisions for the safety of life and health of the public and employees who may be affected by the work for which he is responsible.

Sec. 29.—He will express no opinion which is not founded on adequate knowledge and honest conviction while he is serving as a witness before a court, commission or other tribunal.

Sec. 30.—He will not issue exparte statements, criticisms or arguments on matters connected with public policy which are inspired or paid for by private interests, unless he indicates on whose behalf he is making the statement.

Sec. 31.—He will refrain from expressing publicly an opinion on an engineering subject without being informed as to the facts relating thereto.

* A uniform standard developed by the Engineers' Council for Professional Development for adoption by all engineering societies.